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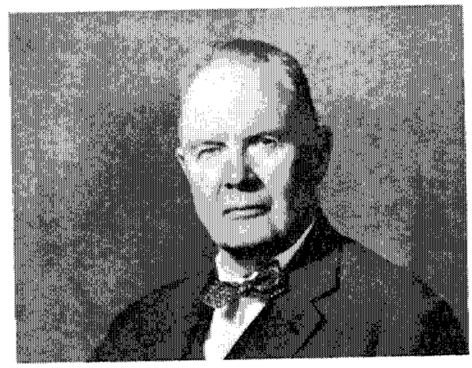
TRUSTEES

AS OF 31 DECEMBER 1962

TRUSTEES

LAWRASON RIGGS

30 April 1881
6 January 1963



Lawrason Riggs was born in St. Louis, Missouri, far from the sea, yet he loved the sea and by his special talents contributed to the development of the marine sciences for nearly forty years. He was the Treasurer of the Institution through its first two decades and a Trustee and Corporation member until his death. He gave unstintingly of himself to the two laboratories in Woods Hole, first becoming Treasurer of the Marine Biological Laboratory in 1924. Then, through his association with Frank R. Lillie, he became involved with the Woods Hole Oceanographic Institution during its incorporation and in drafting the original by-laws. As its Treasurer from 1930 to 1950, he not only kept all the financial records, but also guided its investment program with great skill. During his thirty-three years as a Trustee (Honorary after 1956), Mr. Riggs seldom missed a meeting; and it is typical of his devotion that, despite failing health, he personally sent his regrets for being unable to attend the January 1963 meeting of the Board of Trustees.

Mr. Riggs was also President of the Corporation of the Marine Biological Laboratory from 1942 to 1952, when he became a Life Member of the Corporation and a Trustee Emeritus. As if his work for the two laboratories were not enough, he was also an active Trustee of the Bermuda Biological Station.

Mr. Riggs, a prominent lawyer in the estate and trust field, was a member of the law firm of Riggs, Ferris, Trafford & Syz in New York City, where he made his home. He received his A.B., A.M. and LL.B. from Columbia University. He was a Senior Warden of the Church of the Ascension (Episcopal) in New York City, having served the church in several official capacities for a total of 46 years. Mr. Riggs' other interests and associations were broad and numerous, covering a wide range of business, cultural and charitable activities. Chief among his diversions were sailing, astronomy, Greek, and photography.

At its January 10, 1963, meeting the Board of Trustees of the Institution adopted a resolution expressing sorrow at Mr. Riggs' passing which concluded with this paragraph:

"Lawrason Riggs was a much beloved friend in the village of Woods Hole, who quietly, modestly and unobtrusively went about his work for the scientific community. Each member of the Board of Trustees deems it a privilege to have been associated with him, and his death comes as a deep personal loss to us all."

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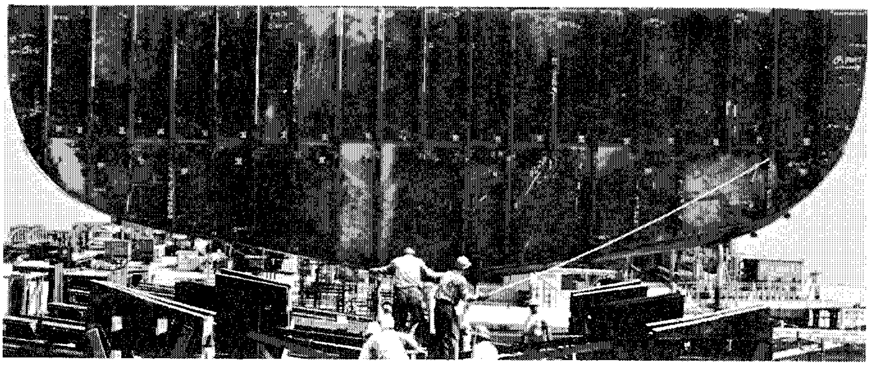


Keel-laying of ATLANTIS II

Citation on Awarding the Bigelow Medal

John C. Swallow

15 August, 1962

"Aluminum scaffold tubing served its purpose ashore for many years, but remained unnoticed by oceanographers until John Swallow found that it can be used to form a floating volume that is less compressible than sea water. A short length of tube, fitted with end plugs and properly weighted, will sink to a predetermined level in the ocean and remain there to drift with the surrounding currents. Since the tube needs ballast, it is convenient to stack batteries and electronics within it to provide power for a high-frequency sound generator, or "pinger" which reveals the position of the tube without direct physical contact that might disturb its free drift.

"This forthright instrument, the Swallow Float, has become the principal tool for the study of deep water circulations. The results of these studies have revolutionized our conceptions of the character of the deep water motions. Instead of the sluggish, widespread drift anticipated from continuity considerations, the deep layers seem to be moving briskly and not in accordance with any known process. Here then, is a scientific fact that challenges the imagination.

"No one is more aware of this than Dr. Swallow. Since 1955, when the first trials of the float were made, there has not been a year in which he has not been at sea in pursuit of further understanding of the character of the deep layer motions. In 1955 and 1956 he worked in the eastern basin of the North Atlantic aboard DISCOVERY II. In the following year he brought DISCOVERY II to join ATLANTIS in a cooperative study of a deep countercurrent off South Carolina. In 1957 he worked again in the eastern basin from the Norwegian research ship HELLAND-HANSEN. Next, in 1958, he worked off Gibraltar. By 1960 he had concluded a year-long investigation of the deep motions to the south of the Gulf Stream. In 1961 he took part in the International Expedition to investigate the Faeroe-Shetland overflow from the Norwegian Sea. During the past winter he joined the ERIKA DAN to measure the deep currents off Greenland and Labrador.

"John Crossley Swallow was born at Newmill, Yorkshire, England, on 11th October 1923. He began his education at Holme Valley School. In 1940 he was awarded a scholarship at St. John's College, Cambridge. He read mathematics and physics for two years after which he joined the Admiralty Signal Establishment, working mainly at the East Indies Station until 1947. He then returned to Cambridge, was graduated with First Class Honors in Physics, and subsequently joined the Department of Geodesy and Geophysics to work on techniques for seismic prospecting at sea. He applied these techniques extensively during a round-the-world voyage of H.M.S. CHALLENGER during the period 1950-1952 and continued this work in the North Atlantic during 1953. He was awarded the Cambridge Ph.D. Degree in 1954 for a thesis on "Seismic Investigations at Sea". He joined the National Institute of Oceanography in 1954 where, one year later, he used his first neutrally-buoyant float for tracking deep water movements.

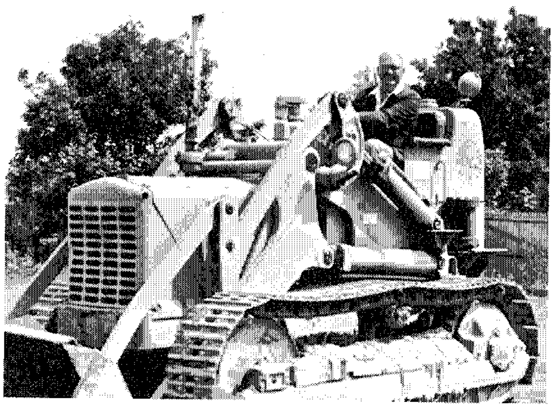
"Dr. Swallow has the rare quality of being almost equally at home with theoretical or practical problems and has a quiet relish for arduous work at sea. The forethought he gives to each fresh effort has won him a reputation for accomplishment in the face of the severe odds which confront anyone who attempts to do new things at sea.

"It is also characteristic of Dr. Swallow to be modest. On being informed of his nomination as Henry Bryant Bigelow medalist, his first impulse was to think that there must have been some mistake, and his second, to go out and clean a few drains to regain his sense of proportion.

"The Henry Bryant Bigelow medal is a new symbol of recognition and honor. In John Crossley Swallow we find not only one to honor by this symbol but also one whose qualities as a scientist and as a man bring significance to the Bigelow medal as a mark of scientific accomplishment".

DIRECTOR'S REPORT

Just at midyear, June 18 to be exact, two events which were widely spaced yet close in spirit signalled a transition from possibilities to actualities, from hopes to facts. For on that bright day, while the keel for the new research vessel ATLANTIS II was being laid in Baltimore, the first ground was turned for our new Research Laboratory in Woods Hole. By year's end, the 210-foot, 2300-ton ATLANTIS II was nearly ready for delivery, and the walls of the new laboratory had risen three stories above the level of Water Street with occupancy four months away.



Christening of ATLANTIS II.
Ground-breaking for biology-chemistry building, 18 June 1962.

With a new ship to expand our sea-going capacity and capabilities and a new laboratory to relieve overcrowding and facilitate research, our major plant needs seemed well on their way toward fulfillment. But other important facilities were being added at the same time. In June, the 99-foot GOSNOLD, a converted Army cargo ship, was added to the fleet for use principally on short cruises in local waters and along the continental shelf. A four-engine DC4-type aircraft, capable of accommodating a scientific party of eight, was acquired and being converted for scientific use, chiefly marine meteorology. And a contract was let for the construction of a 20-foot deep sea research vehicle, capable of diving with two men 6,000 feet into the ocean to make observations and collections never before possible.

Although these dramatic events highlighted the physical side of the Institution's program, they by no means overshadowed the important scientific work which continues to meet high standards of excellence. These programs are discussed later in the Report under headings corresponding to the six scientific departments which were established during the year to place decision-making responsibilities closer to the scientist performing the research. This new departmental organization is another aspect of the Institution's growth, which calls for constant review of administrative procedures on a broad front along with the increased physical facilities.

To assist in making a review of our entire operation, the Board of Trustees during the year authorized the activation of Visiting Committees (p. 13) to evaluate our entire program and make recommendations on how best to meet the impressive challenges of the future. These committees met from October 8-12 to set up procedures, to outline the considerable task they were commissioned to perform and to prepare a first report. We are pleased to note that the committees in general enthusiastically endorsed the scientific program of the Institution and provided an excellent set of recommendations for future guidance. They all agreed to return in the fall of 1963 for a second meeting.

Perhaps the most important cruises started during the year, at least from an international point of view, were those of CHAIN and CRAWFORD to the Equatorial Atlantic. Our ships are participating there in a massive effort to explore the region with thirteen other vessels, ten of them from other countries including Argentina, Brazil, Ivory Coast, Nigeria, Congo, and the U.S.S.R. Plans were also continued during the year to arrange for the Institution's participation in the International Indian Ocean Expedition.

Another highlight of the year was the decision of the Trustees to make a second award of the Henry Bryant Bigelow Medal in Oceanography for Distinguished Achievement in Marine Sciences. The recipient was Dr. John C. Swallow of the British National Institute of Oceanography. Dr. Swallow, along with his many accomplishments spanning an outstanding career in oceanography, is the inventor of the Swallow Float, which has become a principal tool for examining the velocities of the deep-water circulations.

The educational program of the Institution continued to expand in several ways, chief among them being the preparation for three new formal courses in oceanography to be inaugurated in the summer of 1963 using the Ketch ATLANTIS to introduce students to the ocean-going side of the work. An Annual Announcement listing the range of our educational opportunities was published. And our program of public education and information continued with the publication of our periodical *Oceanus,* which, in addition to being mailed to all the Associates, is now on file in major libraries in this country and abroad. The distribution of various materials such as *A Reader's Guide to Oceanography,* and *Research in the Sea* to students and interested laymen has reached sizeable proportions. An attempt is made to answer all pertinent inquiries from whatever source, often requiring rather extensive bibliographic assistance. Thus there is a considerable effort to broaden the base of interest and understanding of the work of the Institution. It is evident that there is much interest among budding scientists, but that good factual material in public libraries has not kept pace with the demand or the interest.

But while there are many efforts and accomplishments to discuss this is essentially a sea-going and sea-loving community, the single highpoint of the year was the construction of ATLANTIS II. Although this fine vessel was not delivered until January 31, 1963, I hope I may be permitted to depart from the protocol of annual reports, and include in this 1962 report a few paragraphs of the remarks made at the dedication of the ship just before departing on her first scientific cruise on February 21, 1963.

Officials and their wives at the launching ceremony for ATLANTIS II.

"Today we now dedicate formally the ATLANTIS II to service in oceanographic research throughout the world. In so doing, we note with pride that ATLANTIS II joins a fleet of research ships with a most distinguished and enviable record. First and foremost in that list is her illustrious predecessor whose name she bears, the ATLANTIS. In addition, we note in order of their appearance in our fleet—ASTERIAS, ANTON DOHRN, RELIANCE, MYTILUS, RELIANCE II, PHYSALIA, MENTOR, SALUDA, DOT III, HAZEL III, BALANUS, CARYN, ALBATROSS III, BEAR, CRAWFORD, YAMACRAW, CHAIN, ARIES, EUGENIE VIII, and by no means least GOSNOLD.

"All of these have sailed from Woods Hole under the auspices of this Institution in pursuit of knowledge of the seas. Each has contributed in a unique way to the history of our Institution.

"In this new ship, the ATLANTIS II, which we dedicate today we believe we have the most capable of all research ships. She represents the culmination of the dreams and plans and compromises of all of us. She demonstrates once again that oceanographers, naval architects, federal officials and ship constructors can indeed cooperate for a purpose and can succeed in that purpose. We do thank most sincerely all those whose cooperative efforts have made this ship possible.

"The affection of each of us for our ships is obvious and unquestioned. But if the ATLANTIS II is to reach the heights of achievement we aspire to in the years ahead, if she is to match in proportion to her capability the record of the ATLANTIS, then more than affection is needed. With larger numbers of scientists and mariners aboard, we will need a degree of cooperation and understanding surpassing even the superb record of the past. This cooperation and teamwork must be carried out in a manner which does not inhibit the freedom of thought and creativity without which our research efforts would wither and die.

"We will need a measure of financial support which to our sponsors may at times seem oppressive. We must continuously remind ourselves that what is at stake is whether or not these new tools for science can be so used as to permit this Institution to rise to new heights of creativity and thus make truly great contributions to our knowledge and our culture. This calls for great leadership, great courage and great ability — all of which I am confident we possess.

"In this spirit of friendly formality and solemnity, we now dedicate the ATLANTIS II in the words of our charter 'to prosecute the study of oceanography in all of its branches, and to the exploration of the seas in accord with the finest tradition of scientific endeavor."

Department of Applied Oceanography

EARL E. HAYS, Chairman

The Department of Applied Oceanography is at present concerned with the following subjects: mooring systems for deep-sea buoys, instrumentation for deep-sea buoys (current meters, temperature recording, sensing, etc.), telemetering systems for oceanographic data, measurement and recording of the temperature structure of the upper 600 feet of water, measurement of waves and currents on beaches, sound transmission predictions from hydrographic data, an information processing center, the development of a specially designed mechanical sound source and the design of two deep, manned submersibles for oceanographic research. These projects are closely related to other important programs of research in the Institution and thus connect the Department of Applied Oceanography to all the others.

Anchored Buoys. The deep-sea anchored buoy program has proceeded along the following two equally important lines: (1) the preparation, setting and retrieving of the buoy stations and the processing of the data from the current meters, and (2) the improvement of the buoys and the addition of telemetering systems to them.

During 1962, a total of 39 self-recording current measuring buoy stations was set. These stations included two series along the Woods Hole–Bermuda line made in March and June. Another of five buoys was made in the Pacific Ocean during May. A three-buoy, 10-mile triangular array near 28° 30′N, 76° 00′W in December 1962 made possible a controlled comparison of the several methods of measuring currents presently used by oceanographers. These data will lead to a fuller understanding of the limitations of the various methods.

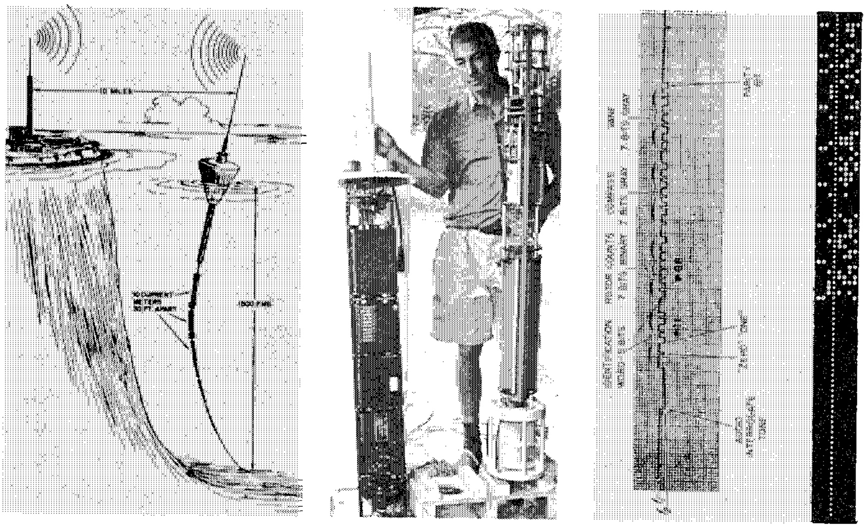
Although the buoy system was designed primarily to measure pelagic currents, it has also been used to study deep-water fouling, corrosion, and mooring performance.

The deep-water buoys, like so many other new oceanographic devices, have been plagued by unexpected problems. The attrition rate due to marine attack on the mooring line was greater than anticipated from the 1961 work. Line has been damaged down to depths of over 1,000 feet, and much of the damage looks as if some creature had rasped the line rather than take a single slashing bite. Speculation has the squid as a possible cause. Squid may be feeding on organisms which attach themselves to the line or become entangled on it. In the process they may employ their rasp-like radula to scrape these bits of food, actually sawing the rope part way through.

Whatever the cause, the parting or the weakening of line have resulted in equipment losses. The weakened line often parts while the string of instruments and anchor is being hauled, making this a dangerous operation. We are endeavoring to identify the culprit or culprits in this problem and devise means to eliminate or reduce the effect. Several approaches are being investigated, such as line impregnation, line protection or the use of wire through the critical depths. To reduce losses due to weakening of the line anchor release devices are also being developed. One type will operate on a time schedule; another type will operate on command from the surface. The loss of a buoy string with its accumulated data is an expensive loss; if the data is recovered, the loss is not as severe.

Telemetering Systems. Certain special experiments make it desirable to change sampling rates at will and to look at the data while it is being taken. Radio telemetry is a possible solution to both problems, and a program has been underway for some time to develop a reliable instrument for telemetering both current and temperature data. Problems being studied are concerned with data acquisition, information transfer from instrument to buoy, signal conditioning, radio propagation, life and reliability.

Several systems were set up and tested during 1962. In December a mooring with 10 telemetering current meters was set near Bermuda. The experiment was controlled from the Bermuda Biological Station, where continuous recordings were taken. The output was also monitored with excellent results at Southampton, Long Island, and at our own receiving station at Waquoit, Massachusetts. More than 1,500 current vectors were received and stored on punched tape from current meters at 10 depths.



Moored telemetering buoy system; the instrument; the message; coded for the computer.

The telemetry problem, of course, is not one of simply radioing a single signal that is proportional to temperature or current or some other parameter, but is a complex problem of handling information from several sources and coding it into suitable form for reliable transmission that can be made compatible for use with a computer. Such systems have been developed for the Buzzards Bay Wave Tower, for a vertical string of seawater temperature sensors, and for the current meters.

The problem of data acquisition has not been limited to the buoy program. An airborne meteorological data system for the R5D aircraft has been designed and some construction completed. This system will provide a plurality of sensor inputs to a magnetic tape through EM subcarrier oscillators. A similar system has been developed and used for field studies of beach erosion and accretion.

Computers. As oceanographers obtained high-speed data acquisition systems, it became obvious that computers must be used to process the data. The rental and use of a Recomp II was a step in the right direction, but this computer does not have the capability required now. The decision was made to advance several stages in the computation and information processing fields. A leasing agreement was concluded with General Electric Company late in the year for a GE 225 Computer to be delivered in the spring of 1963. A computer of this size needs a professional staff, which is being acquired.

It is our intention that the information processing center be run as an "open shop". That is, any scientist may write his own programs, participate in the actual running of the data and effectively be one of the center's personnel while working on his problem. Plans also call for remote consoles which will enable frequent users to use the computer from their own offices. The goal is to make the computer a convenient aid to science, to enable investigators to try new ideas and thoughts about their data in ways which are impossible without a computer. Programs for the GE 225 are now being written, and a considerable number of the problems to be handled are being investigated.

Many of the significant acoustic transmission properties of the oceans are obtained from hydrographic data. As acoustic instrumentation and techniques advance, the derivation of acoustic information from the hydrographic data becomes more critical. Processing these data and calculating the expected transmission are also problems requiring the use of a computer along with a realistic approach to assessing variations in data. A new method of curve fitting and interpolation has been developed that is superior to the Lagrangian and similar polynomial interpolation methods. Very likely this will become the standard method for interpolation on the GE 225 computer.

Mechanical Sound Source. An experimental mechanical sound source is expected to be operative in 1963. Designed to give a high peak pressure with controlled pulse shape, this will be a valuable tool in acoustics and geophysics. The performance of a preliminary smaller model indicated this source will meet design specifications.

Deep-Sea Submarine. A positive step in extending the capability of the Institution to work under the sea surface was taken with the letting of a contract to General Mills Incorporated to design and construct a 6,000 foot depth, two-man submersible. Equipped with windows and a mechanical arm, and having good maneuverability, a range of 25 miles and an endurance of 24 hours, this craft should enable scientists in many fields to make investigations until now essentially impossible. Designed to be very stable, the craft should make an excellent platform for performing midwater measurements and will allow selective sampling of the bottom and observational collection of marine life *in situ*. Personnel at the Institution are primarily concerned with the safety and operational requirements of the craft and in monitoring the design being done by General Mills. The design and construction of the

ALUMINAUT together with some analyses and testing of certain design features have continued to interest several of the staff.

In addition, the Department of Applied Oceanography has supplied electronic and mechanical engineering services where needed by other departments of the Institution.

Department of Biology

JOHN H. RYTHER, Chairman

Distribution of Nutrients. Investigations of the quantitative distribution of essential plant nutrients, particularly phosphorus and nitrogen, in coastal and offshore waters have been continued. Ammonia-nitrogen, often neglected in such studies, was found to have possibly greater significance than nitrate or nitrite in the illuminated surface waters where plant growth can occur.

A new bioassay method for phosphorus indicates that standard chemical analyses for this element may seriously overestimate the amount available in seawater for phytoplankton nutrition. Preliminary tests were also made of the qualitative and quantitative distribution of organic phosphorus compounds in the sea and the source, fate and turnover rates of the more important compounds.

Microbiology. Biochemical and cytological examination of the marine nitrifying bacterium, *Nitrosomonas oceanus* became possible through successful use of mass culturing techniques. Electron microscopy of the organism and of the more common terrestrial nitrifying bacteria revealed the presence of a cytomembrane organelle of unknown function, hitherto undescribed in bacteria, structurally comparable to the chloroplasts of plants.

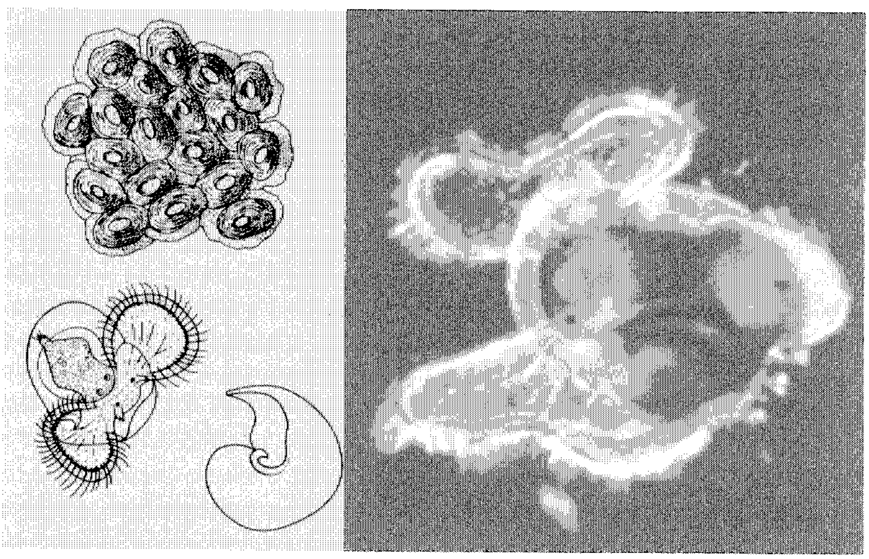
The cytology, sexual reproduction, and comparative physiology of marine diatoms interested several members of the permanent and visiting staff. The vitamin B_{12} requirement of diatoms from different habitats has been determined with some evidence that the amount varies at different stages in the life cycle. Both qualitative and quantitative aspects of carbohydrate and protein excretion by phytoplankton have also received attention. A new sensitive fluorescence method was developed for the measurement and differentiation of chlorophyll and its decomposition product phaeophytin. By this means the relative fractions of living and dead phytoplankton in different environments may be assessed.

Enumeration of phytoplankton species in the northwestern Atlantic between Nova Scotia and Venezuela illustrate the inter-relationship between the hydrography, chemistry of sea water and the kinds and numbers of organisms present. Faster growing diatoms predominate in the colder, richer waters to the north and in the regions of upwelling off the South American coast, while flagellated forms prevail in the warmer, stratified, nutrient-poor, mid-oceanic regions.

Zooplankton. Extensive zooplankton collections were made at various depth intervals with new opening and closing nets on two cruises during the past year, with the taxonomy and distribution of copepods receiving the major attention. The deep water forms were found to be numerically sparse, taxonomically diverse and geographically far more ubiquitous than the restricted surface-living species. A taxonomic revision of the genus *Candacia* was completed.

The trophic relationship between phytoplankton and zooplankton populations was considered by means of an intensive sampling program in the Gulf of Maine, following a specific water mass by means of parachute drogues. Correlated with this survey have been physiological experiments on several zooplankton organisms in the laboratory. A new technique was developed to measure the metabolism of planktonic and benthic organisms at their ambient temperatures and pressures.

Evidence was obtained which indicated that the "patchy" distribution of plankton may be due, in part, to the behavior of the animals in relation to the wind-driven Langmuir circulation of the surface water. Dissolved and particu-



Pelagic larvae of gastropods.

late organic matter may also be transported towards the surface by adsorption to rising bubbles and further concentrated into windrows by the action of the Langmuir cells.

Benthic Biology. An enumeration of the deep-sea bottom fauna has been made along a transect between Woods Hole and Bermuda, revealing significantly larger numbers of animals than previously described from such areas. The deep-sea benthos may be characterized as a relatively sparse but highly diverse community with lack of dominance by any individual species, presumably representative of populations living in environments which have been stable for long periods of time.

The skeletomusculature, external morphology, functional anatomy and comparative "naupliology" of the subclass Cephalocarida, class Crustacea, have now been described as a part of the attempt to document the phylogenetic position of these recently discovered, primitive Crustacea.

Embryological studies were made of various marine invertebrates among them the gastropods, *Nassarius* and *Anachis,* and the tube worms, *Hydroides* and *Spirorbis.* These include descriptions of their larval stages and an inquiry into the environmental factors which influence gametogenesis and the liberation and settling of the larvae.

Fishes. Extensive exploratory fishing, frequent examination of commercial landings and increased tagging efforts all contributed new information on the distribution of pelagic fishes, with efforts concentrated on the continental shelf from Georges Bank to Cape Hatteras. Additional data were accumulated on tunas, particularly for the bluefin and bigeye. Results of the cooperative gamefish tagging program (49 returns from 2766 releases) included recovery in Norwegian waters of three giant bluefins tagged in the Florida Straits. The outstanding result, however, was our greatly increased knowledge of the general autumnal distribution of the broadbill swordfish along the continental slope and apparent differences in its habitat according to size and sex. This species was taken in quantity throughout the fall by long-line fishing at night in the vicinity of the 500-fathom curve from Georges Bank to the Hudson Canyon.

The taxonomy of larval fishes was greatly advanced by the acquisition of a custom-built soft X-ray unit capable of contact microradiography of larvae and juveniles as well as conventional radiography of adult specimens. Four species of larval and juvenile tunas can now be distinguished by differences in their bony structure.

Further ichthyological work was based on collections of skates and rays collected by U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries vessels operating along the South Atlantic coast of the United States and in the Gulf of Mexico from hitherto little-explored depths of 100-600 fathoms.

Department of Chemistry and Geology

BOSTWICK H. KETCHUM, Chairman

Organic Compounds. An extremely complex mixture of organic compounds has been isolated from sea water. Some of these are in concentrations as low as one part in one thousand billion parts of water. Some components were identified during the year. For example, straight chain hydrocarbons in the C_{14} to C_{35} range were found in near-shore water, and large amounts of fluoranthene and pyrene hydrocarbons were present in the aromatic fraction. This analysis is continuing.

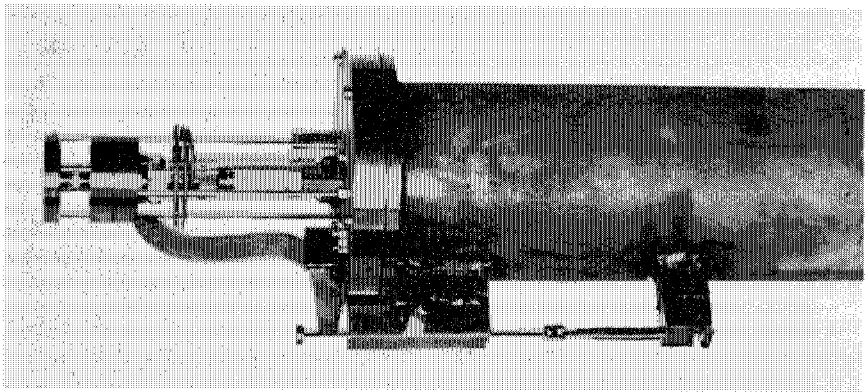
Biochemical sources of dissolved marine hydrocarbons were sought in samples of zooplankton. The saturated hydrocarbon fraction of zooplankton from the Gulf of Maine consists of a nearly pure nonadecane ($C_{19}H_{40}$). This is not predominant in samples from the Woods Hole area, suggesting that the nonadecane may be due to an organism occurring regularly in the Gulf of Maine, but not in the immediate vicinity of Woods Hole. Further work will attempt to identify the responsible organism or organisms and to search for this hydrocarbon in sea water.

There are indications from these studies, plus those on hydrocarbon assemblages in fossils, that saturated and aromatic hydrocarbons are distributed more widely in nature than had previouly been supposed. It appears that in many respects the hydrocarbon assemblages of marine sediments and fossils resemble those from soils, petroleum, air and various organisms.

Metabolic Processes of Marine Animals. A new apparatus was developed to investigate the effects of temperature and pressure on the respiratory metabolism of planktonic and benthic animals. It has now been used successfully to measure the respiratory rates of "scattering layer" crustaceans under various temperatures and pressures. These respiratory measurements are essential to an undertanding of the contribution these organisms make to the ecology of the open sea. Some organisms can live for rather extended periods of time in an environment containing no oxygen. Their metabolic activities continue without oxygen by means of fermentation processes, such as the production of lactic acid. The amounts of lactic acid produced by the fiddler crab, and its subsequent disappearance, appear to be commensurate with the oxygen debt incurred by the animal under anoxic conditions.

Chitin Synthesis. A method has been developed for studying the synthesis of chitin, which forms the exoskeleton in Crustacea. The mechanism for the synthesis of this complex organic molecule is being examined by using an enzyme derived from the epidermis of softshell crabs. Since various Crustacea are abundant in the zooplankton, this is an important process in the economy of the sea.

Trace Elements in the Sea. The analysis of trace elements in "pure species" collections of plankton continue to show interesting differences in the ratio of elements when compared with sea water. For example, the sea water ratio of Sr:Ba is about 900, but the highest value for this ratio in plankton was only about 300 and the lowest 10. The metabolic processes of animals, their vertical migrations, and the sinking of their remains will obviously have a considerable influence on the vertical distribution of elements which are accumulated or discriminated against in biological processes.



Triggering and filtering mechanism for new large volume water sampler.

One of the difficulties in studying trace elements in the ocean is the necessity of acquiring sufficient concentrations of them from large volumes of sea water to permit the accuracy required by the analytical technique. Our long-range program is to map, in time and space, the distribution of these trace elements, so that we may study their variations with the same degree of confidence and accuracy that now obtains for variations in salinity and temperature.

This will require the development of rapid and accurate analytical techniques which can be used on shipboard. A start in this direction has been the use of anion exchange resins to separate elements which can exist as anion complexes in a chloride medium of approximately pH 8.0. In this way, zinc, copper, and lead can be removed from sea water and subsequently eluted from the resin column with appropriate acids. This method effectively separates zinc, for example, from cations such as sodium, magnesium, calcium and potassium, which are far more abundant in sea water.

Our knowledge of the basic physical chemistry of the complexing of trace constituents of sea water is rudimentary. One problem under investigation is the binding of heavy metals with ion exchange resins and clays, both in the presence and absence of simple organic compounds. Apparently, when the zinc is complexed with the simple amino acid, glycine, it is less effectively removed by the ion exchange resin, suggesting that the zinc-glycine complex is not bound by the resin.

Clay minerals, on the other hand, bind the zinc even when it is complexed with the glycine. Studies of these effects must be continued and evaluated to determine whether the presence of variable amounts of organic compounds may influence our analytical findings on the distribution of trace metals.

Fission Products. The distribution of fission products from fallout was measured on samples collected from the four U.S. weather ships in the Atlantic Ocean and from the Institution's own vessels in both the Sargasso Sea and in the equatorial regions. These observations confirmed our conclusions that the fallout delivery over the oceans is mediated in different ways from that over land. The concentrations of strontium-90 were definitely higher in the Sargasso Sea than in the equatorial regions, with those near the seasonal thermocline being greater by a factor of two.

Salt Bridges. The use of salt-bridges for both GEK current measurements and for the determination of detailed pH and salinity distributions was further developed. The waters of the continental shelf south of Nantucket show variations in pH and salinity distribution determined in this way which are fully as intricate as the associated thermal structure in this area.

Interlaboratory Cooperation. The cooperative evaluation of analytical methods was continued at a meeting in Woods Hole in which participants from eleven major oceanographic laboratories in the United States and one from Canada carried out an intercomparison of methods for the determination of dissolved oxygen by the Winkler method.

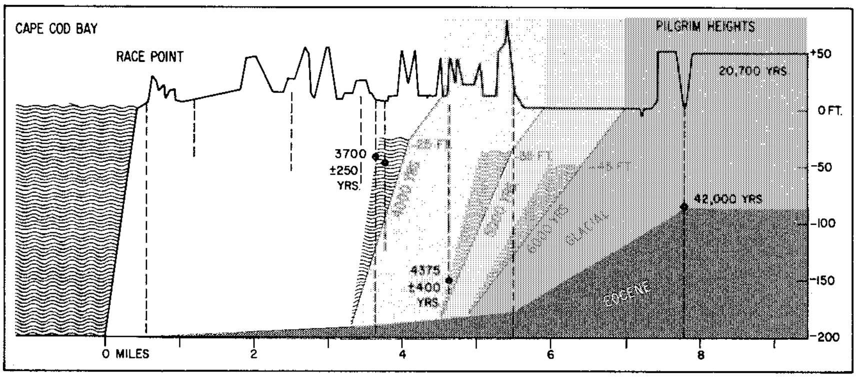
Geology of the Continental Shelf. In July, a new program in geology was started for the study of the continental shelf and slope between Maine and Florida in cooperation with the U.S. Geological Survey. Four geologists from the U.S. Geological Survey have been assigned to Woods Hole, and the total group of combined personnel will ultimately be fifteen or sixteen.

For the first six months, the staff has been fully occupied in obtaining equipment and in conducting a literature search of previous observations throughout this geographical area, including the hydrography, the related distribution of temperature, salinity and sound velocity, and the runoff of the various rivers. New topographic charts have been prepared from data of the U.S. Coast and Geodetic Survey as well as unpublished data from the Institution and from the Lamont Geological Observatory at Columbia University.

A laboratory for analysis of organic materials in the sediments has been set up, and about 100 samples obtained from the continental shelf between Block Island and Nova Scotia by the Bureau of Commercial Fisheries have been analyzed for inorganic and organic carbon and organic nitrogen.

Other parts of the program include an evaluation of the sediment texture using pipettes and a new version of the Woods Hole sand analyzer. The rock and gravel content of the samples and the mineralogy of the materials also bear upon the origin and geological history of the continental shelf.

Geology of Outer Cape Cod. The geology program concerning the beaches on outer Cape Cod was continued, and the results described in a manuscript recently completed for publication. The Provincetown Hook is apparently a wedge of sand deposited along the side of a pre-existing ridge of Tertiary sediments. It is advancing seaward, but the cliff section is retreating at a rate of about 2.8 feet per year. Some radiocarbon dates for the structure of outer Cape Cod have been obtained. The upper fluvial glacial outwash identifiable in the outer Cape has been dated at approximately 20,000 years, but the Provincetown Hook appears to be only 5,000 or 6,000 years old.



Section showing growth of Provincetown Hook in Post-Glacial time.
Evidence derived from wells (dashed lines) and carbon dates.

These beach studies emphasize the need for more fundamental investigations on the mechanisms of sand transport by shoaling waves over complicated bottom topography. Data collection requires the simultaneous measurement of wave heights and lengths, the orbital velocity of the water movement and the distribution of suspended sediment in the water at various locations in a transect normal to the beach. Some progress has been made, but the refinement of these observations will depend upon the development and calibration of more sophisticated methods for measuring the various important characteristics of the system.

The changes in the structure and topography of the beaches has been evaluated on a broader geographical scale through aerial photography. The available aerial photography now covers a span of more than a decade, and additional still pictures are available from the Coast and Geodetic Survey. As might be expected, the major beach changes occur after hurricanes or other major storms, and the chronology of these changes is clearly shown in the photographic record.

Sediment and Circulation Relationship. The interrelationship between the distribution of sediments and the circulation of the water in various shallow bays is demonstrated by the distribution of pelagic Foraminifera in the sediments. The Foraminifera from the open sea can be identified and their subsequent distribution in the bottom sediments is an indication, not only of the present-day circulation, but also of its consistency and stability in the past.

Foraminifera distribution data have been collected in the Gulf of Venezuela, the Gulf of Darien and the continental shelf south of Woods Hole. The intimate relationship of the hydrography and the type of rainy season in the general region of the Gulf of Venezuela is documented by a manuscript now in preparation.

"Tongue of the Ocean." A study of the bathymetry of the "Tongue of the Ocean", Bahamas, was completed this year. The field work and laboratory analysis of the data took about two years. The project report includes bathymetric charts, bottom photographs, and a discussion of the character of the superficial sediments.

Department of Geophysics

J. B. HERSEY, Chairman

Hydroacoustics and Related Physical Oceanography. The scientific interests of the geophysics department extend into the fields of physical oceanography, marine biology, and submarine geology, as well as into the fields generally regarded as part of submarine geophysics. This situation arises because of the common bond provided by hydroacoustical techniques and the intimate interplay between disciplines required for understanding the influence of various oceanographic factors on sound in the sea.

Sound Transmission. A study of long range sound transmission from the North America Basin to a set of hydrophones mounted on the slope of the Bermuda platform was continued. Observational techniques were refined so as to analyze the many sound pulses received from a single transmitted pulse in order to identify their specific acoustical paths through the ocean.

In the past certain pulse sequences were successfully identified with a water mass near Bermuda having distinctive acoustical properties by shooting explosions at specified depths at regular intervals from a ship moving along a track. This accentuated the characteristic of the acoustical field under study. Subsequently, it became desirable to increase the pulse rate well above that ordinarily maintained in shooting explosives (one shot every two minutes), and repetition rates of a pulse every ten seconds were achieved with the use of the

Sparker or the Boomer. With this technique, refined distinctions between closely neighboring paths were made, and time-dependent effects such as the influence of surface and internal waves observed. In cruises to the Norwegian and Mediterranean Seas in 1960 and 1961, sound transmission experiments were conducted over short distances to observe coupling effects between sound channels occurring one above the other in the water column (an example is the permanent SOFAR channel and a surface isothermal layer).

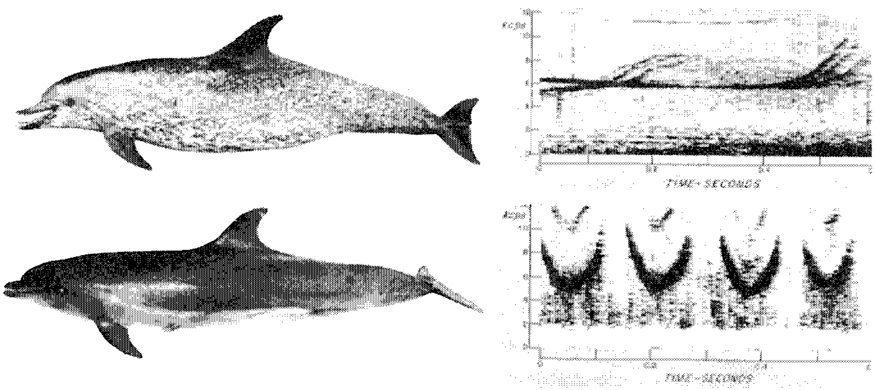
The effect of internal waves on short range horizontal transmissions was also determined from the results of observations in which the Sparker or Boomer was used as the sound source and ten hydrophones distributed along the thermistor chain (i.e., from the surface to 550 feet) as the receivers. Thermistor chain recordings taken along the transmission paths immediately following each test provided excellent information about the water structure. The received sound energy was examined spatially and spectrographically and is now being compared with appropriate theoretical models based on ray and normal mode theories. This simple recitation of data reduction requires a tremendous amount of work in the laboratory and digital machine programming on the theoretical models. The computing program was successfully completed and was in use over the last several months of the year.

Bottom Reflectivity. Great progress was also made toward automating measurements of various acoustical data taken from a ship underway or in the course of a specific experiment where very large numbers of observations are necessary. A semi-automatic system was developed for reading the integral $\int p^2\,dt$ of the bottom echo in echo sounding (p is the acoustic pressure; t is time). Through various stages of development, more than 40,000 observations made during the past two years are being processed by digital computers. Our scientific goal in the immediate program (a doctoral dissertation) is to associate acoustic reflectivity with the gross and fine scale shape of the ocean floor and with the composition and state of the materials of the bottom. To this end special experiments were conducted in shallow water where the bottom could not only be sampled and photographed, but also observed directly by free divers.

Our longer range objective is to enable hydroacousticians to select, measure, and store any wave train observed at sea. Then the analysis can proceed either afloat or ashore without the weeks or months of tedious routine work which has hitherto been required even in digital processing systems.

Sound Velocity. Sound velocity was determined in the customary vertical profiles over an ocean area bounded roughly by the Bahamas, Puerto Rico, and the Bermudas. The results clearly reveal the shallow structure near Bermuda noted above and, further, bring out a pattern in the deeper water (about 1000 meters deep) suggesting a confluence in this area of cold water coming from the southeast with warmer water from the north. Preparation for this work included a significant improvement in the instrument system measuring sound velocity and in the upward pointed echo sounder which signals the depth of the instrument.

Natural Sounds of the Sea. It is extremely difficult to identify the cause of natural sound conclusively. This difficulty is especially exasperating because many sounds which obviously seem to have a biological origin cannot be identified with certainty as to individual species or even as to classes of sea animals without long and painstaking study attended by good fortune. Such a survey has been underway for some years and has required the cooperation of many scientists and technicians. This year a report was completed in the form of a sound recording of the natural vocalizing of 18 species of whales and porpoises. An accompanying paper identifies the species with sound spectrographs of their vocalization.



Stenella plagiodon. Tursiops truncatus. Porpoises, their recorded squeals.

Sound Scattering and other Studies Relating to Pelagic Organisms. Mid-water sound scattering in the sea is chiefly attributable to strata of animals in the upper 1000 meters called deep scattering layers. Study of these layers continued during 1962 together with other researches relating to pelagic life.

Particular attention was paid to the frequency dependent aspects of sound-scattering in a peculiar layer in the slope water off the northeastern United States. The identity of this layer is not yet certain but a 10- or 12-inch fish appears to be the responsible scatterer.

An examination of the hypothesis that the broad-band sound-scattering regime of the oceans is descriptive of the faunal provinces of the upper 1000 meters was also begun. In this connection fishes collected on CHAIN Cruise 17 from the Romanche Trench to Bermuda were examined using the facilities of Harvard's Museum of Comparative Zoology.

Other problems investigated concern pelagic sharks, the bluefish (*Pomatomus saltatrix*), and microbioluminescence in surface and near-surface waters.

Internal Waves. Various studies of our accumulation of thermistor chain records are underway, and some have been published. Many intensive series of observations have been made in the Strait of Gibraltar in cooperation with oceanographers at the SACLANT Research Center at La Spezia, Italy. During 1962 no new data were taken, but preliminary results from a CHAIN cruise late in 1961 forwarded from La Spezia show a close correlation between internal waves of large amplitude in the Strait and acoustic scattering layers there.

Significant new evidence on the characteristics of internal waves was obtained following three different approaches. Long single-track recordings are being examined to measure and to present statistically the distribution of apparent periods and amplitudes and to relate the latter to their geographic distribution. Three-dimensional surveys based on special maneuvers of the observing ship have as their immediate objective measuring the distribution of periods, taking into account the direction of their propagation. The third study still in a preliminary stage at the year's end, is designed to estimate acoustic transmission through complex structures.

Thermal Fronts. Since 1960, the thermistor chain was used in repeated traverses of the ocean between Bermuda and the Bahamas. On each visit a temperature front was found near 30° N, 70° W, where near-surface temperatures drop 1.5° to 2.0° C along tracks proceeding from southwest to northeast This year, two transits of this area six weeks apart located that front and also another one 130 miles to the south. GEK tows through the fronts show that the water in the warm wall flows eastward at a speed well above the noise of the GEK. Their local shape is obviously complex and changes with time, but it is not known how far the fronts extend nor where.

Seismic Reflection. Seismic reflection observations in deep water with the continuous seismic profiler, first achieved last year, have been carried out this year on the continental slope and rise south of New England and Georges Bank, on the Bermuda Rise and over the abyssal plains of the North America Basin, and over the Puerto Rico Trench and the outer ridge to the north of it. Everywhere penetration below the bottom consistently has a travel time between 0.5 and 1.25 seconds after the bottom echo. Reflecting surfaces thought to be layers of sediment are found to be generally flat and smooth, whereas deeper reflectors, whether stratified or not, appear to be more complex and have higher relief. These latter reflectors have been traced over the outer ridge to an outcrop in the north wall of the Puerto Rico Trench where basalts, cherts, limestone and other sedimentary rocks were recovered by dredging.

Special acoustical triangulation techniques were employed to fix the position of the dredge. These made use of hydrophones mounted at the ends of two 50-foot booms supported athwartships, and two more hydrophones mounted beneath the ship to provide long mutually perpendicular base lines for triangulation. The sound signal came from a pinger mounted on the cable and fitted with a precise clock for controlling the ping rate. Thus, accurate travel time from apparatus to ship can be maintained despite lack of direct control of the pinger from the ship. Using this system we can locate submerged instruments with far greater accuracy than heretofore. In the dredging operations we are assured of placing the dredge on the outcrop in a depth of about 3300 fathoms. Earlier in this same cruise serpentinite was dredged from about 4200 fathoms, structurally well below this outcrop and possibly well below the top of the deepest crustal layer characterized by a velocity of about 6.5 km/sec.

The observations complement similar records taken by the staff of the Lamont Geological Observatory with whom the group at the Institution are cooperating in analyzing data and interpreting results.

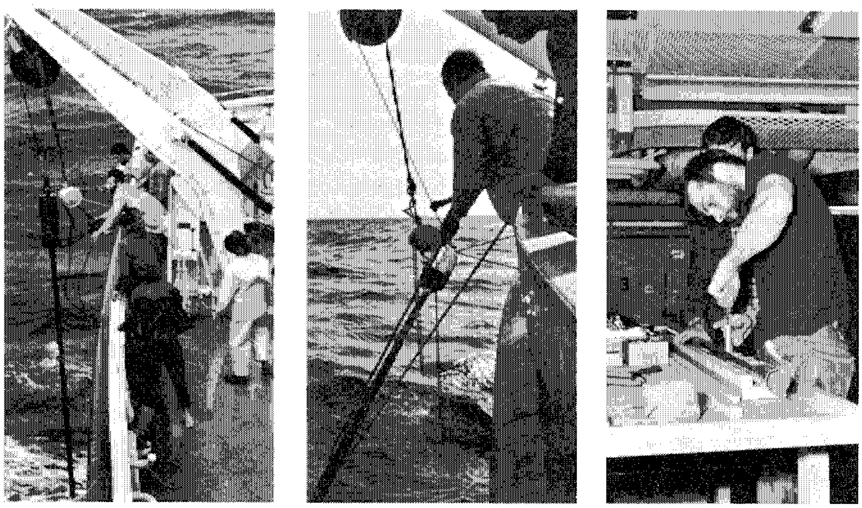
As part of the broad question concerning the age of the Atlantic Ocean, now increasingly suspected as forming during the Cretaceous period, there is especial interest in comparing the indirect evidence derived from seismological methods and the direct evidence from bottom sampling done in locations selected with the aid of geophysical methods described above.

Gravity at Sea. This year, a fully-automated system was added for measuring gravity from a surface ship, and a start was made in measuring the earth's magnetic field aboard the same ship from which the gravity apparatus and a continuous seismic profiler are operated. This combination has long been recognized as a most powerful means to reduce the indeterminateness inherent in the interpretation of geophysical measurements.

The gravity system combines a La Coste-Romberg Sea Gravimeter with an IBM 1710 Control System. It prints and stores original gravity data, and computes and prints free-air and sea Bouguer anomalies. These are based on appropriate reductions derived from navigational and bathymetric data fed separately into the computer.

Gravity observations were made on five cruises of CHAIN between early July and late December to various locations in the western North Atlantic. During all cruises except the first, gravity and seismic reflection observations were made simultaneously. During the last cruise of the year, to the Puerto Rico Trench and the outer ridge to the north, the gravity results gave promising correlation with earlier seismic refraction and gravity measurements. These studies are part of a continuing evaluation of an area on the outer ridge where the crustal layers appear to be uncommonly thin and thus present a good prospect for the site of the Mohole.

Heat Flow from the Earth's Interior. Heat flow from the earth's interior, a fundamental indicator of internal state, was recorded over a broad ocean area bounded by Bermuda, the Bahamas, and the north wall of the Puerto Rico Trench. The results show little change throughout this region, and further show that the heat flow there is close to the world average. An extension of heat flow studies with comparable control is anticipated for the western North Atlantic in search of evidence about the probability of active convection currents in the mantle beneath this area.



Heat probe over the side. Retrieval of heat probe and bottom core.
Removing samples from the core.

Bottom Topography. Other geophysical and geological investigations center upon the shape of the ocean floor and the properties of the sediments. Many thousands of miles of echo sounding track were examined to present the distribution angles of slope.

Continued studies of ponding of sediments in deep, enclosed basins suggest the possibility of identifying modern and ancient sediment ponds and hence provide a means of gauging Recent epeirogenic movements in the ocean basins.

Difficulties in measuring low velocities in sediments and rock by the seismic refraction method leaves in serious doubt the velocity structure and hence the general nature of shallow layers between the ocean floor and the layer having a velocity about 5.5 km/sec. Oblique reflection techniques have been developed, through the use of radio-sono-buoys, Sparkers and Boomers, for measuring the velocity in these layers and their reflecting properties. During the year several excellent records were made, and the results from the cruises of 1961 were analyzed. Many more locations must be examined in detail, but at this writing a first rate set of instruments is in hand and it is now hoped to proceed with the scientific observations.

Determination of the magnetic susceptibility of sediments in the deep-sea is made especially difficult because they are so weakly magnetic. During the year, an especially sensitive magnetometer has been developed which has the required sensitivity and, further, has been made compatible with a practical device for semi-automatic processing of the cores. This approach to the magnetics of deep-sea sediments holds great promise and its continued development and use is anticipated.

During the year, six graduate students, four from the Massachusetts Institute of Technology, one from Bryn Mawr College and one from the University of Chicago, have participated in the research program of the department. One worked on the semi-automatic measurement of the energy in sonic pulses discussed above. Three are concerned with various aspects of the properties of bottom reflection (the first-mentioned student is applying his system to this problem). One is attempting to determine the attenuation of sound in sediments strictly *in situ*. The fifth has just completed his doctoral dissertation based primarily on seismic records of the structure of the earth's crust in the western basin of the Mediterranean. The sixth is examining the structures and history of the continental slope and rise south of New England and Georges Bank. His principal tool thus far has been the continuous seismic profiler. Through his efforts the quality of our seismic reflection observations has been considerably improved with an excellent linear directional receiving array.

Trends in Data Handling. Newly available commercial photo-copying equipment make it feasible for us to reproduce echo sounding, thermistor chain, and continuous seismic profiling records on micro-film. The Institution file of data in these categories is now being recorded in this way. This capability opens up great possibilities such as automatic reduction of data plotted against time to the same data plotted as a function of distance traversed by the ship, as well as rapid, convenient transmission of data to the National Oceanographic Data Center, and exchange of complete data with other scientists.

Another trend in our program of great significance to our scientific product is the increased use of automatic storage and data reduction techniques. In cooperation with IBM an approach has been worked out which will permit us to record very nearly all of the data ordinarily taken during our cruises in a digital storage medium and in a form that can both be stored for later use by machine program and be viewed in a suitable analog display at the time of observation on the ship. Such a capability has been badly needed for acoustical and seismic studies. These have been seriously delayed or put off entirely in the past for lack of suitably developed automatic recording and processing equipment.

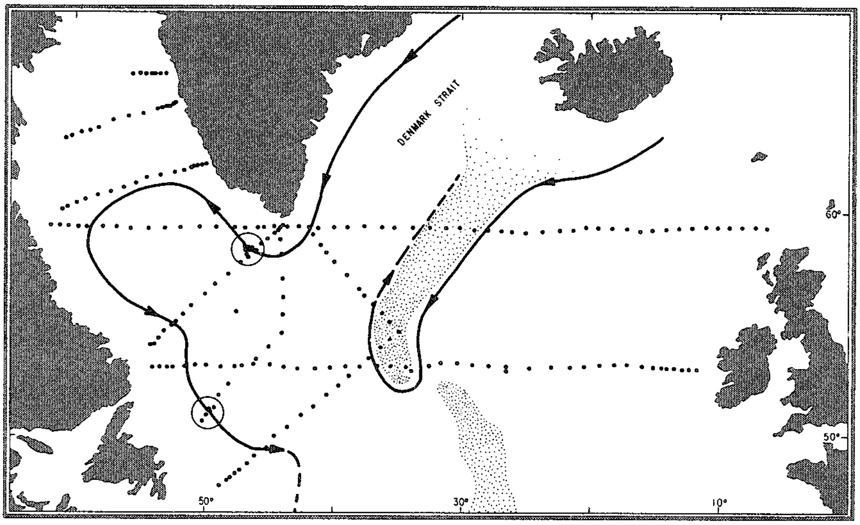
Department of Physical Oceanography

FREDERICK C. FUGLISTER, Chairman

The Physical Oceanography Department is principally concerned with the circulation of the Atlantic Ocean and adjacent seas. The problems are approached primarily by water analyses, that is, by studies of the distribution of temperature, salinity and oxygen, and secondly by calculating the geostrophic currents on the basis of the density distribution. In recent years there has been more and more interest in the deep circulation and in measuring the velocities directly with neutrally buoyant floats, drogues and current meters.

The Northern North Atlantic. The principal observational program of 1962 was from 17 January to 4 May on board the M/S ERIKA DAN under charter from J. Lauritzen of Copenhagen, Denmark. The purpose was to investigate late winter conditions in the Labrador Sea and Davis Strait with a ship suitable for navigation in the vicinity of ice.

It has been clear for many years that any formation of new deep or new bottom water in the Atlantic must take place within the Labrador Basin. One reason for the cruise was to determine if any large scale, deep convection of this sort was taking place. From the data collected on the ERIKA DAN cruise, it is concluded that no deep convection took place during the winter of 1961-1962, and that it is unlikely that any convection to depths greater than 1200 meters has taken place in recent years.



ERIKA DAN stations with arrows to indicate deep overflow from the Norwegian Sea. Larger circles position actual current measurements.

On the other hand, it appears that there was a considerable overflow of cold water from the Norwegian Sea into the North Atlantic. Data collected on an earlier CHAIN cruise indicate that 5 million m^3/sec are contributed from this source over the Iceland-Faroes Ridge. Of this, however, only 1.5 million m^3/sec appears to be pure Norwegian Sea water, the remainder being Atlantic water entrained into the overflow.

Through its temperature/salinity relationship, the overflow water can be traced as far as 53° 30′N, flowing to the south along the eastern slope of the Mid-Atlantic Ridge. At some point, slightly to the south of ERIKA DAN's 53° 30′N section this water evidently passes through a gap in the Ridge and subsequently can be traced flowing northward along its western slope.

A further deep overflow from the Norwegian Sea occurs in the Denmark Strait between Greenland and Iceland. This overflow has distinctly different temperature/salinity characteristics. The flow of this current was measured, by direct observations and by geostrophic calculations, on two occasions on the ERIKA DAN cruise, off Cape Farewell and to the north of the Grand Banks. Volume transport calculations have not been completed, but it seems likely that a rapid and regular flow was taking place during the periods of observation.

The Mediterranean Sea. The other major survey of 1962 was ATLANTIS Cruise 275, from early January to late April, the third and last in a series to the Mediterranean Sea. The objectives of these cruises were the determination and observation of the processes involved in vertical circulation and the formation of deep or intermediate water.

With the exception of areas off Tunis and Libya, the entire Mediterranean Sea from Gibraltar to the Black Sea was covered by the Woods Hole observations in 1961 and 1962. In particular, such key areas as the Ligurian, Adriatic and Aegean seas were reasonably well sampled. These key northern regions are the initial meeting grounds for dry polar continental air and warm maritime air masses. Here the Mediterranean water is transformed by cooling and evaporation to sufficient density to sink and disappear below the surface.

In contrast to the slight change in the Western Mediterranean is a significant seasonal change occurring in the lower Aegean Sea as ascertained from the temperature/salinity analysis. Periodic and aperiodic large scale changes occur in the Adriatic, which is a strong contributor to Eastern Mediterranean circulation.

In addition to the work on ATLANTIS Cruise 275, direct current measurements were made with drogues in the southern Aegean Sea through the cooperation of the ARAGONESE, the SACLANT research vessel from La Spezia, Italy. Most of the measurements were made at depths of 200 meters, where the oxygen data indicated a marked sinking of water to that level. There was a large amount of horizontal turbulence. In one case a cyclonic gyre with a radius of ten miles persisted for approximately three days with a perimeter velocity of 40 cm/sec. No simple flow in or out of the Aegean basin was observed.

Some oceanographic stations on the ATLANTIS Cruise were made in conjunction with the Yugoslavian vessel BIOS in the Adriatic Sea. Cooperating foreign scientists aboard the ATLANTIS were P. Tchernia, P. Guibout and A. de Quay from the Laboratoire d'Océanographie Physique in Paris; A. Skrivanic of the Instituta za Oceanografiju i Ribarstvo at Split; H. Kolokythas, director of the Greek Hydrographic Service; and A. de Maio of the Naval Institute in Naples.

The Gulf Stream System. Problems associated with the circulation, especially the deep circulation, in the Gulf Stream System were examined in several ways during 1962. Many of the studies relied heavily on data obtained during the multiple-ship survey of 1960. Since observations taken on that survey indicated that, in the area southeast of New England, the Gulf Stream extends to the bottom in very deep water, some new theories were developed and many more attempts were made to measure directly the deep currents in the System.

One new theory suggests that, if the current extends to the bottom, the bottom topography may impose a fundamental control on the path of the Gulf Stream at all depths and that this control, rather than an instability, is responsible for the observed meander patterns.

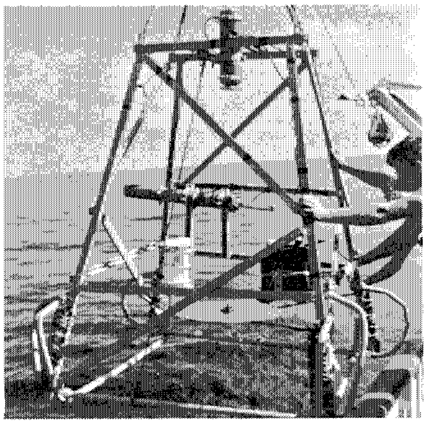
This possibility was confirmed by an order-of-magnitude analysis of the gross vorticity balance of the Stream, for parameters appropriate to the current dimensions east of Hatteras, far from the continental slope, and to the deep velocity measurements of 1960. The analysis revealed that a Stream path must represent approximately a combination of a stationary Rossby wave and a "topographic wave", dynamically analogous to the former, but produced by forced variations in the depth of the current. In other words, at least in an integrated sense, steady-state conservation of absolute potential vorticity prevails.

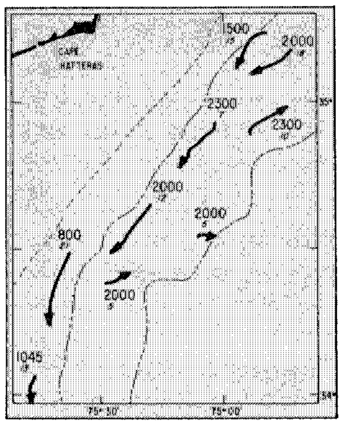
With a number of reasonable approximations, it became possible to transform the gross vorticity balance from a sum of integrals to a non-linear (but tractable) ordinary differential equation describing current paths controlled by the mechanisms of the Rossby and topographic waves. By introducing actual bathymetric data and appropriate initial conditions for the observed current paths, a solution was obtained corresponding to each of these observed paths. Since the topographic wave generally dominated the Rossby wave, the calculated paths tended to meander about the isobaths. They agreed sufficiently well with the observed paths to confirm the consistency of the Gulf Stream meander patterns with the idea of topographic control.

On various occasions during 1962, direct deep current measurements with neutrally buoyant floats and drogues were made in and near the Gulf Stream

System. The westerly and southerly flowing "deep western boundary" current was observed south of Georges Bank and off Cape Hatteras. On the October cruise of the ATLANTIS several bottom current observations were made using a large tripod carrying an Edgerton camera and strobe unit which at regular intervals took pictures of a small rotor-driven counter and a compass a few inches above the bottom. These photographs showed currents of less than 4 cm/sec. To avoid upsetting the tripod, the ship had to hold its position very precisely in a current that often exceeded four knots — a maneuver accomplished with great skill by the ship's officers.

At the same time as these observations were being made on ATLANTIS, the CRAWFORD was making closely spaced oceanographic sections across the current using the new *in situ* salinometer and making GEK and bathythermograph observations. The two ships progressed down Stream together from one location to the next in order to maintain the synoptic nature of the survey insofar as possible.





Camera type bottom current meter. Tracks of Swallow floats, October 1962. Small numbers are current velocities (cm/sec).

This study clearly shows the deep western boundary current carrying water south near the continental shelf and under the surface Gulf Stream. Only two observations, one at 2,000 meters, the other at 2,300 meters in deeper water show currents moving in essentially the same direction as the surface Stream.

The study of eddy momentum transports in the Florida Current, mentioned in the last annual report, was continued. Velocity measurements off Jacksonville, Florida, show a surface eddy flux of momentum essentially similar to earlier observations off Onslow Bay and in the Straits of Florida. The pattern of all these calculations is that on the shoreward side of the Florida

Current there is a transfer of kinetic energy at the surface from the perturbations of the current (the "shingles") to the time-average current. A possible role of the "shingles" is that they are an important mechanism in maintaining the energy of the basic flow.

Direct current measurements were also made in places away from the Gulf Stream System; in a region bordering the northern Antilles island arc, in the "Tongue of the Ocean" and over a large area south and southeast of Bermuda. The last of these differed from the rest in that they were radio drogues located and tracked by plane rather than by ship. Three of these sixty-four foot diameter radio drogues were set in mid-June at depths of 1,000 meters near 29° N Lat., 65° W Long. Eighteen search flights were made, the last one in November. The floats described a great anticyclonic eddy approximately 34,000 square miles in area.

In July, the CHAIN made a short cruise to investigate the low pressure trough southeast of the Grand Banks (mentioned in the last annual report) and to train students taking the summer course in introductory physical oceanography. On four of the six sections made across this area the low pressure trough was observed; on the remaining two there was an abrupt transition from the warm Gulf Stream water to the cooler water typical of the northern gyre without an intermediate trough of extremely cold water.

Neither the temperature nor the current field suggested that any considerable volume of Gulf Stream water passed across a line drawn between the "tail" of the Grand Banks and the intersection of the 40th parallel and the 40th meridian. On the other hand the currents were weaker and more diffuse than the hypothesis suggested and the oxygen measurements gave evidence that a considerable exchange of water must have taken place across the trough in the recent past. A Canadian cruise under the leadership of Dr. C. R. Mann of the Bedford Institute of Oceanography is planned for the spring months of 1963 to explore this general area further. This will assist in planning the Institution's work in this little known region scheduled for the early months of 1964.

Abyssal Circulation. With the aid of certain direct current measurements, a study of the abyssal circulation in the western basin of the North Atlantic is being made based on oceanographic station data from "Gulf Stream '60", the IGY survey and other deep observations made aboard Institution vessels since 1954. The physical idea of this study is that stream lines in a steady state might be indicated by intersections between constant potential temperature surfaces and isohaline surfaces.

The main charts prepared for this work are isotherms of potential temperature at the bottom and at levels of 4800 meters and 4000 meters, and isobaths and isohalines on selected potential temperature surfaces (1.85°, 2.0° and 3.5° C.) in the "Gulf Stream '60" area.

In addition, isobaths and isohalines on the 1.85° C. surface have been prepared for the entire Western Basin. Isohalines on this surface indicate that the main abyssal circulation pattern in the Western Basin may consist of a large cyclonic gyre. A comparison between the dynamic topography chart, referred to the bottom, and several measurements of deep current in the "Gulf Stream '60" arc suggests that no significant bottom countercurrent exists beneath the Gulf Stream or south of it in the basin north of Bermuda.

Temperature Variations in the Surface Layer. Average temperatures from the surface to 1,000 feet in the North Atlantic have been summarized in a series of monthly profiles along eight arbitrarily chosen meridians. These profiles clearly show that, though the averaging process tends to smooth any given values, major ocean currents can still be easily recognized. The entire series of profiles shows the average month to month changes in temperature and positions of the currents.

Temperature ° C in the N. Atlantic at a depth of 200 meters.

A paper presenting average temperature conditions at a depth of 200 meters in the North Atlantic has been completed. It is being published by the American Geographical Society as Folio 2 of the Serial Atlas of the Marine Environment.

Spectral Power Spectrum of Internal Waves. A study was made of the spatial power spectrum of internal waves observed in an area to the east of the island of Madeira. Ten spectra have been computed from these data and in all cases show that the internal wave power increases with wave length from the minimum resolvable wave length of about 100 meters to the maximum resolvable length of about 1000 meters. No spectral peaks were found within these limits. The large tidally driven internal waves observed in the Straits of Gibraltar have also been examined. Water velocities associated with these waves were in some cases as high as 100 cm/sec.

Circulation on the Continental Shelf. The program concerned with the water circulation on the continental shelf and its annual cycle of temperature and salinity since 1955 has continued. To determine these features, (a) a series of observation posts was established from Maine to Georgia at selected lightships and shore locations where daily temperature and salinity measurements were made and drift bottles released; (b) drift bottles and sea-bed drifters were released by our own ships and ships of cooperating agencies over the continental shelf from Cabot Strait to Florida in an effort to examine the seasonal and annual trends in the surface and bottom circulation; (c) a series of current measurements were initiated by means of moored current meters and drogued telemetering drift buoys at selected locations.

The following agencies have cooperated in this work: the Biological Station at St. Andrews, New Brunswick, of the Fisheries Research Board of Canada; the Bureau of Commercial Fisheries Laboratories at Boothbay Harbor, Maine, at Woods Hole, Massachusetts and at Beaufort, North Carolina; the Bureau of Sport Fish and Wildlife Biological Laboratory at Sandy Hook, New Jersey; the U.S. Weather Bureau Atlantic Weather Project; the U.S. Air Force Weather Observers on the Texas Towers; the U.S. Coast Guard Lightship crews, and the Virginia Institute of Marine Science at Gloucester Point, Virginia.

About 23,000 drift bottles and 7,800 sea-bed drifters were released during 1962, and about 10 and 15 percent respectively were recovered. The drift bottle data are being combined with those from previous years into a series of 12 charts depicting the direction and speed of the non-tidal drift as well as the percentage recovery from 30-minute rectangles for a 12 month series covering the east coast of North America from Cabot Strait to Florida. Much additional Canadian data will be obtained for these charts through the collaboration of Dr. Louis Lauzier of the Fisheries Research Board of Canada Biological Station.

Experiments were conducted with drogued telemetering buoys between Cape Cod and Cape Hatteras. The results show that the velocity profiles across the shelf are related to the density field, that the salinity distribution almost completely dominates the ultimate shape of the density distribution and that during the summer months the temperature distribution plays a more important role in the density distribution than during other seasons. Land drainage can have an appreciable effect on the salinity distribution over a period of from two to five months after peak runoff.

Department of
Theoretical Oceanography and Meteorology

COLUMBUS O'D. ISELIN, Chairman

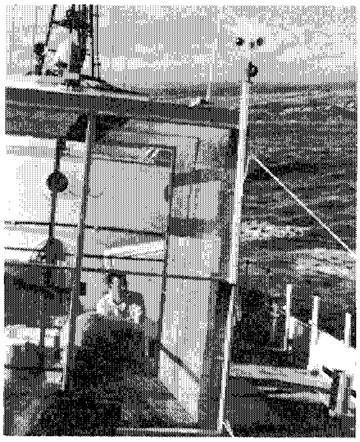
Space charges from sea salt particles. Hawaii continues to provide an ideal natural laboratory for studies on the physics and chemistry of orographic rains and of airborne sea salts over the sea. By selecting a region along the shore where a great amount of bubbling takes place and where dense clouds of particles were consequently rising from the sea, it was demonstrated that a positive charge is associated with these particles. It was also possible to measure space charges of up to 2000 fundamental units cc^{-1}. The flux of organic material from sea to air may have some bearing on the charge transfer mechanism. With a simple technique airborne particles can be sampled and a test made for the presence of surface active organic material. This material was always present in such quantities as to suggest that particles from the sea carry at least a monolayer, on the average, when they are ejected into the air.

By monitoring the electricity carried by precipitation simultaneous data on the potential surface gradient were obtained. The rain current was generally positive, but there were negative surges at the beginning and end of showers. This was especially interesting because the electrical properties of rains from clouds which do not reach the freezing level in the atmosphere have been but little studied. It appears that the mechanism of rain formation in such clouds is more complex than originally believed.

From laboratory experiments, it appears that great quantities of positive charge are associated with the salt particle cloud that forms when non-charged saline drops are allowed to fall onto a hot surface. Such tests should throw some light on the problem of charge separation from bubbles breaking at the surface of the sea. In certain geological ages in the past, when volcanic activity was much more intense than at present, there may have been sufficient charge separation at the lava-sea contact zone to increase significantly the positive charge of the atmosphere.

Salt-induced convection and clouds. The amounts of condensation on airborne sea-salt particles were estimated for different humidity and rate-of-rise conditions. These observations suggest that the amounts of latent heat released due to condensation may be an important factor in the transport of moist air parcels from near the sea surface to cloud-base altitudes. By extending the estimates of condensational heating, a series of tentative temperature lapse-rates may be computed. These may be characteristic within certain ascending moist air parcels during wind storms and other conditions in marine air. Furthermore, it was demonstrated that 20 to 40 mg of finely divided sea-salt particles per kg of air, when added to the lower atmosphere in oceanic areas should result in sufficient heating to cause ascending motions and perhaps even cloud formation.

Deuterium and sodium content of raindrops. Raindrops taken from within or near the bases of orographic shower-producing clouds in Hawaii have an inverse relationship between deuterium and drop size. While it had been hoped that the isotope concentration might serve as an indicator of the nature of drop growth processes in trade wind clouds, the results thus far have actually only led to specific suggestions for improving the sampling procedures in such studies.



A Faraday cage to measure electrical space charges in the atmosphere.
A rain recorder in a clearing in the rain forest.

A photometer was also devised to determine the sodium content of individual or of a relatively few raindrops. This should prove to be the most direct way to explore the idea that large salt nuclei form large drops, the small ones small drops and related problems.

Water vapor in the sub-cloud trade wind air. It had been suggested that trade wind shower cells are more likely to originate in more humid air parcels adjacent to drier parcels. If the air is forced to ascend and condensation begins, the more moist parcels gain buoyancy before the drier ones. Hence, there is a greater probability that they form the nuclei for showers. However, it was not known whether such relatively large (1-2 km in diameter) parcels existed throughout a large part of the sub-cloud layer. In the absence of data to illustrate this point, a three-plane expedition was organized to study the horizontal and vertical moisture structure on 10-20 minute runs at 400, 800 and 1200 feet off the eastern shore of Eleuthera Island in the Bahamas. Here the trade winds blow with considerable variation in speed, stability and cloud cover. Statistical studies revealed that a differential temperature of 0.23°C would be generated by the condensation of excess water vapor of the more moist parcels if the air is forced up a mountain slope. This temperature difference seems sufficient to initiate a shower. Only weak relationships were noted for relationships between wind speed, cross-wind and parallel-wind differences.

Air-Sea Interaction. Theoretical studies of the vertical heat flux led to an explanation of the depth and temperature of the convective, isothermal surface layer. Both quantities were related to a balance between absorption of visible radiation within the layer and the loss of heat by evaporation, conduction and infra-red radiation at the surface. Variations in the profile below the isothermal layer are caused primarily by vertical motion. This theoretical work and the development of suitable instruments is preliminary to tests in the field.

Sea smoke and convection. When very cold air flows over a relatively warm ocean the surface steams ('sea smoke'). This occurs from the poles to the tropics in calm and in gales. The intensity of the steaming increases as the sea-air temperature increases, so that its vertical extent ranges from a meter to a thousand meters. In sea smoke, the visibility may be as low as 100 m, while its liquid water content of up to a few tenths of a gm/m^3, if supercooled, represents an icing hazard to shipping. It is possible to compute the conditions for the onset of steaming of a given water surface, the critical air-sea temperature difference (likely range 7° — 18°C) is found to increase with increasing water temperature and salinity, but to decrease with increasing humidity of the overlying air. These values, as well as other conclusions of the above hypothesis have been substantially verified by observation.

From what is known of convection over land, profiles of the distribution of temperature with height in the air over the sea have been computed and it has been demonstrated that, for a given air-sea temperature difference, the thickness of the thermal boundary layer increases with increasing wind. It is concluded that for air and sea with given properties the height of sea smoke increases with increasing wind.

Wind-generated waves. When wind blows over a large body of water, waves are generated which seem in general to progress in the direction of the wind. However, when viewed from near the surface, such as on board a vessel, the waves seem to be travelling in many different directions at rather broad angles to the wind. The objective of measuring the directional spectra of waves is to characterize the relative intensities of waves as a function both of their angular frequency, or wave length, and their direction of travel.

A method for measuring sea-wave spectra by their diffraction of radio waves was tested from the Helio-Courier aircraft. The radio energy returned from the sea surface at any given radio wave length should be proportional to the intensity of the sea waves of comparable wave length. Thus, by sweeping over a broad range of radio wave length the full spectrum of ocean waves can be examined. By changing the heading of the aircraft the relative intensity of sea waves progressing in various directions can also be determined. When fully developed, the method should provide a very rapid means for surveying the wave state over the open oceans, where no satisfactory method is presently available.

Measurement of the directional wave spectra may also be determined by the use of an array of surface height detectors arranged along a line and fixed in space. This method has been used in Buzzards Bay since 1959. It has taken much time to develop an accurate means for measuring the waves, reducing the data for use in a digital computer and in carrying out the actual analysis of directional wave spectra. The line array method is similar to that of the radio direction finding except that all the functions of the radio receiver are simulated by the digital computer. While not as rapid as the airborne radio technique, it is capable of perceiving very fine detail.

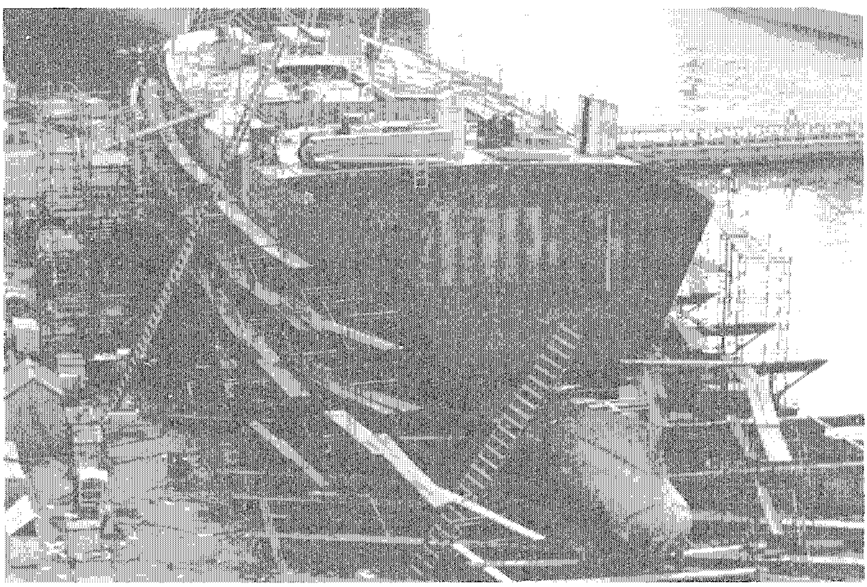
The first analysis has just been completed and the measured results, supplemented by visual observations, indicate that sea waves are not a random, chaotic process, as is generally assumed, but that their directions of travel are closely related to the wave frequency. Thus, waves of a particular frenquency appear to travel only in specific and discrete directions relative to the wind.

Hydrodynamical model studies. On completion of a new hydrodynamics laboratory, preliminary studies were undertaken on the effects of wind stress on a rotating water mass, of thermal convection in a rotating system, and an extension of earlier work on the instability of laminar boundary layers in a rotating system. In connection with the laboratory measurements of the latter, it was proposed that the Langmuir circulation cells in the ocean are a manifestation of the instability of the spiral boundary layer near the surface of the ocean. To test this hypothesis, measurements of the angle between the surface wind and the directions of the wind rows were attempted. In some cases these observations were made from a small boat and in others they were observed by scattering papers over the surface of the ocean to indicate the wind rows and by using smoke flares to show the wind direction. In all cases, the wind direction was to the left of the flow direction in agreement with the theoretical prediction.

Dynamics of ocean currents. Work has continued on refining and improving mathematical models of ocean currents. As during the last several summers a course in advanced geophysical fluid dynamics was held at Woods Hole for selected students and other interested visitors. Much effort went into the organization of this course which was conducted for the first time on a seminar basis. A number of original papers resulted which are being prepared for publication.

FACILITIES — ADDITIONS AND IMPROVEMENTS

Sea-Going. At year's end, the new research vessel ATLANTIS II was nearing completion at the Maryland Shipbuilding & Drydock Company in Baltimore. This 210-foot, 2,300-ton ship financed by a grant from the National Science Foundation, was designed for all-weather oceanographic research from the ice fringe to the tropics. ATLANTIS II was designed for a cruising speed of 12 knots, a range of 8,000 miles and has accommodations for a scientific party of 25 and a crew of 28. She has a steel hull and twin propellers driven by two uniflow reciprocating steam engines. Operating noise and vibration has been reduced to a minimum by special design features throughout the ship.



ATLANTIS II abuilding.

For extra maneuverability, the ATLANTIS II is equipped with a bow propeller mounted in an underwater tunnel athwartships which moves the bow to port and starboard. In addition to the standard controls on the bridge, the ATLANTIS II has four remote control stations automatically connected to the rudders and engines, and located so that the operator can coordinate the movements of the ship while observing the scientific work on deck. There are four major laboratories and air-conditioning throughout the ship.

The GOSNOLD, a 99-foot Army cargo vessel built in 1949, was purchased from Institution funds for conversion for scientific work. It was bought to meet a growing need for a ship that could be worked inexpensively on day trips or short cruises in local waters and along the continental shelf. When fully converted, the GOSNOLD will have accommodations for a scientific party of seven and will carry a crew of six.

Also, during the year, a contract was signed with the General Mills Company to build for the Institution a deep sea research vehicle capable of taking a pilot and one scientific observer to a depth of 6,000 feet. This 10-ton, 20-foot submersible will be built to operate for up to ten hours at considerable depths at a speed of 2.5 knots. It will be equipped with scanning sonar, an echo sounder, underwater telephone, lights, underwater television, cameras and a mechanical arm for collecting specimens. This project is sponsored by the Office of Naval Research.

Also acquired during the year was the NOBSKA, a 26-foot bass boat, which will be used for utility purposes and inshore scientific work. The NOBSKA is a gift from Donald F. Carpenter, a member of the Associates of Woods Hole Oceanographic Institution.

The EUGENIE VIII, a 59-foot sportsfisherman acquired in 1961, was sold by the Institution since it did not prove sufficiently economical to operate.

Shore-Based. During 1962 two major projects to improve facilities were initiated or carried forward.

Filling portions of the swamp area north of the Blake building was continued and an access road constructed over the newly acquired property at 49 School Street. This work has provided approximately 1½ acres of trafficable land, a portion of which is used for the storage of large equipment and for parking for approximately 120 employees' cars.

On June 18th, 1962, ground was broken for the Laboratory for Marine Science on the corner of School and Water Streets. Work has proceeded rapidly and the building is to be occupied during the months of May and June of 1963. It provides 44,000 square feet of space. Most of the biological and chemical work at the Institution is to be housed in this building. In addition, it will become the computing center for the Institution. Special features of this laboratory will include environmental rooms adjustable over a wide temperature range; air conditioned rooms for special experimental and instrumental work; an aquarium; dissecting and X-ray facilities for ecological and ichthyological studies and a lecture hall seating approximately 250 people.

In the Air. During the year, the Institution also acquired a four-engine R5D (C-54 in Air Force parlance) aircraft on continuing loan from the Office of Naval Research. After its conversion, the plane will be used chiefly for meteorological studies, but it will also be equipped for tracking instruments attached to buoys (whether free-floating or anchored) taking temperature readings and geological and geochemical research.

MAJOR CRUISES OF WHOI VESSELS

January to December, 1962

ATLANTIS — Days at Sea—269 — Total Miles Sailed—31,889

CRUISE	DATES	AREA OF OPERATION	DAYS	CHIEF SCIENTIST
275	9 Jan.–26 April	Eastern Mediterranean	108	A. Miller
276	1 May–19 May	Munro's Shipyard		
277	22 May–28 May	Bermuda	7	H. Sanders
278	30 May–3 June	Bermuda	5	P. Sachs
280	13 June–23 June	Sea Mounts	11	R. Pratt
281	26 June–1 July	Sea Mounts	6	W. Dow
282	7 July–11 Aug.	San Juan, P. R.	36	J. Reitzel
283	27 Aug.–31 Aug.	Local	5	H. Sanders
284	5 Sept.–10 Sept.	Slope Waters	6	R. Scheltema
286	18 Sept.–29 Sept.	Blake Plateau	28	J. Barrett
287	30 Sept.–27 Oct.	Bermuda	12	J. Ryther
288	4 Nov.–17 Nov.	Bermuda	14	R. Snyder
289	28 Nov.–18 Dec.	Nassau	21	P. Stimson
279	June 7 - June 7	Buzzards Bay	1	B. Bunce (LMM 6/93, from deck log)

BEAR — Days at Sea—118½ — Total Miles Sailed—5,823

CRUISE	DATES	AREA OF OPERATION	DAYS	CHIEF SCIENTIST
	Jan.-Feb.	At Dock		
269	28 Mar.–30 Mar.	Norlantic Shipyard		
270	1 Apr.–13 Apr.	Local	13	W. Dow
272	28 Apr.–3 May	Cape Cod Bay	7	W. Schevill
274	6 May–10 May	Cape Cod Bay	5	W. Schevill
277	28 May–30 May	Buzzards Bay	3	W. Dow
278	16 June–22 June	Sea Mounts	7	T. Stetson
279	25 June–30 June	Slope Water	6	L. Bennett
280	10 July–30 July	Off Carolina Coast	21	E. Bunce
281	6 Aug.–15 Aug.	Narragansett Bay	10	L. Breslau
283	20 Aug.–30 Aug.	Local	11	R. Pearson
284	4 Sept.–7 Sept.	Local	4	W. Dow
285	8 Sept.–9 Sept.	Local	2	L. Breslau
288	25 Sept.–26 Sept.	Local	2	W. Dow
290	1 Oct.–3 Oct.	Newport	3	L. Breslau
291	4 Oct.–11 Oct.	Newport	8	A. Nalwalk
	15 Oct.	Dyer's Dock		

GOSNOLD — Days at Sea—41 — Total Miles Sailed—3884

CRUISE	DATES	AREA OF OPERATION	DAYS	CHIEF SCIENTIST
	19 Mar. Purchased			
1	16 May–22 May	Miami to Woods Hole	7	
2	24 July–5 Sept.	Port Canaveral	44	D. Bumpus
3	4-5 October	Tarpaulin Cove	2	K. Emery
4	23 Oct.–13 Dec.	Norlantic Shipyard		

MAJOR CRUISES OF WHOI VESSELS
January to December, 1962

CHAIN — Days at Sea–221 — Total Miles Sailed–32,009

CRUISE	DATES	AREA OF OPERATION	DAYS	CHIEF SCIENTIST
22	12 Jan.–18 Jan.	A.E.C. Line–Bermuda	7	N. Corwin
23	22 Jan.–8 March	Munro's Shipyard		
24	13 Mar.–25 Mar.	Buoy Line	13	W. Richardson
25	2 Apr.–30 Apr.	Caribbean Area	29	J. Ryther
26	1 May–1 June	Caribbean Area	32	C. Yentsch
27	9 June–19 June	Buoy Line	11	W. Richardson
28	6 July–24 July	Grand Banks	19	L. Worthington
29	29 July–14 Aug.	Bermuda	17	D. Caulfield
	15 Aug.–20 Aug.	Munro's Shipyard		
30	22 Aug.–30 Aug.	Bermuda Rise	9	J. B. Hersey
31	4 Sept.–7 Sept.	Slope Water	4	J. B. Hersey
32	11 Sept.–21 Sept.	Slope Water	11	R. Backus
33	25 Sept.–6 Oct.	Bermuda	12	W. Richardson
34	18 Oct.–13 Sept.	Puerto Rico Trench	57	J. B. Hersey

CRAWFORD — Days at Sea–196½ — Total Miles Sailed–21,061

CRUISE	DATES	AREA OF OPERATION	DAYS	CHIEF SCIENTIST
72	10 Jan.–31 Jan.	Bermuda Buoy Line	22	C. Parker
73	20 Feb.–23 Feb.	Off the Cape	3	L. Breslau
74	8 Mar.–18 Mar.	Bermuda Buoy Line	11	C. Parker
75	26 Mar.–30 Mar.	Gulf of Maine	5	R. Conover
76	24 April–5 May	Norlantic Shipyard		
77	14 May–18 May	Gulf of Maine	5	R. Conover
78	23 May–5 June	Gulf Stream	14	G. Volkmann
79	8 June–27 June	Buoy Line	20	C. Parker
80	29 June–3 July	Continental Shelf	5	J. Teal
81	10 July–31 July	Off Carolina Coast	22	J. Ewing
82	3 Aug.–9 Aug.	Gulf Stream	7	G. Clarke
83	10 Aug.–15 Aug.	Gulf of Maine	6	R. Conover
84	18 Aug.–26 Aug.	Gulf Stream	9	P. Mangelsdorf
85	4 Sept.–6 Sept.	Slope Water	3	C. Yentsch
87	17 Sept.–19 Sept.	Continental Shelf	3	F. Fuglister
88	28 Sept.–27 Oct.	Carolina Coast	30	F. Webster
89	31 Oct.–21 Nov.	Parker Buoy Line	22	C. Day
90	27-28 November	Banks	2	C. Yentsch

EUGENIE VIII — Total Miles Sailed—400

CRUISE	DATES	AREA OF OPERATION	DAYS	CHIEF SCIENTIST
15	16 Jan.–30 Jan.	Miami to Bahamas & back	13	G. Clarke

VISITORS FROM ABROAD

January-December, 1962

IAN E. ALFORD
University of British Columbia

MASATERU ANRAKU
Hokkaido University, Hakodate, Japan

NORMAN F. BARBER
Dominion Physical Laboratory, New Zealand

J. O. BEAUMONT
University of Cambridge, England

JOHN M. BENNETT
University of Sidney, N.S.W., Australia

Y. K. BENTOR
Geological Survey of Israel

H. P. BERLAGE
Rijk Universiteit, Utrecht, Netherlands

E. L. BOUSFIELD
National Museum, Ottawa, Canada

TRYGVE BRAARUD
Universitet i Oslo, Norway

LUIS R. A. CAPURRO
Direccion General de Navegacion e Hidrografia, Argentina

ERIK DAHL
University of Lund, Sweden

NORBERTO DELLA CROCE
Universita de Genova, Italy

GÜNTER DIETRICH
Institut für Meereskunde, Kiel, W. Germany

M. J. DUNBAR
McGill University, Montreal, Canada

P. DE WOLF
Zoological Station, Den Helder, Netherlands

K. N. FEDEROV
United Nations Educational, Scientific and Cultural Organization, Paris

PETER FOXTON
National Institute of Oceanography, Great Britain

FRANCIS C. FRASER
British Museum (National History), London

ROBERTO FRASSETTO
SACLANT Laboratory, La Spezia, Italy

BRIAN FUNNELL
University of Cambridge, England

A. C. GILSON
Freshwater Biological Association Ambleside, Westmoreland, U.K.

JUAN C. GONZALEZ
University of Puerto Rico

HANS HAMMARGREN
International Meteorological Institute, Stockholm, Sweden

JOHANNES HAMRE
Directorate of Fisheries, Bergen, Norway

H. HOESTLANDT
Université de Lille, France

CARL V. JENSEN
Meteorological Institute, Norway

H. R. JITTS
Division of Fisheries and Oceanography, C.S.I.R.O., Cronula, N.S.W., Australia

ROBERT JOHNSTON
Marine Laboratory, Aberdeen, Scotland

HIDEO KAWAI
Tôhoku Regional Fisheries Research Laboratory, Japan

TERUYOSHI KAWAMURA
Hokkaido University, Hakodate, Japan

MARIUS LECOMPTE
University of Louvain, Belgium

HERMOD LILAND
Meteorological Institute, Norway

R. M. LOVE
Marine Station, Aberdeen, Scotland

S. M. MANTON
British Museum (National History), London

IRENE MANTON
Leeds University, England

G. MARLIER
Brussels, Belgium

JOTARO MAZUZAWA
Japanese Meteorological Agency

A. MOREL
Université de Paris, France

TAKAHISA NEMOTO
Whales Research Institute, Tokyo

A. J. ODDERA
Argentine Antarctic Institute

SVANTE ODEN
International Meteorological Institute, Stockholm

WALDEMAR OHLE
Plön, Germany

MAKOTO OMORI
University of Hokkaido, Hakodate, Japan

ALAN K. PEASE
Institute of Oceanography, British Columbia, Canada

P. J. S. RAJ
Madras Christian College, Tambaram, India

J. REUSS
Institut für Meteorologie, Darmstadt Technische Hochschule

WILHEM ROHDE
Institute of Limnology, Uppsala, Sweden

ROBERTO F. RODRIGUES
Brazilian Navy

VISITORS FROM ABROAD

January-December, 1962

KATSUKO SARUHASHI
Meteorological Research Institute, Tokyo, Japan

JACQUES C. SENEZ
Centre National de Recherches Scientifiques, Marseille, France

M. A. SHANT
Department of Fisheries, Tel Aviv, Israel

LARS GUNNAR SILLÉN
Royal Institute of Technology, Stockholm

C. P. SPENCER
Marine Science Laboratory, Anglesey, U. K.

NIE SPRONK
Amsterdam, Netherlands

EINAR STEEMANN NIELSEN
Danmarks Farmaceutiske Højskole, Copenhagen

ROOBAERT STEPHAN
Niquet, Antibes, France

JOHN C. SWALLOW
National Institute of Oceanography, Great Britain

MARY SWALLOW
National Institute of Oceanography, Great Britain

GUNNAR THORSON
Marinbiologisk Laboratorium, Helsingør, Denmark

TETSUYA TORII
Chiba University, Japan

M. TUFAIL
Department of Zoology, University of Karachi, Pakistan

CARPART VOES
NATO Subcommittee of Oceanography, Brussels, Belgium

ERIC WEBB
Commonwealth Scientific and Industrial Research Organization, Australia

PETER WONZEL
Caracas, Venezuela

GEORG WÜST
Universität, Kiel, W. Germany

ISAMU YAMAZI
Seto Marine Biological Laboratory, Kyoto University, Japan

Architects' sketch for new laboratory.

PERSONNEL

PAUL M. FYE	Director
BOSTWICK H. KETCHUM . .	Associate Director for Biology and Chemistry
COLUMBUS O'D. ISELIN . . .	Henry Bryant Bigelow Oceanographer
WILLIAM S. VON ARX . . .	Oceanographer at Large

Scientific Departments

The following were in the employ of the Institution for the twelve-month period ending December 31, 1962 (an asterisk indicating part-time throughout the year):

APPLIED OCEANOGRAPHY

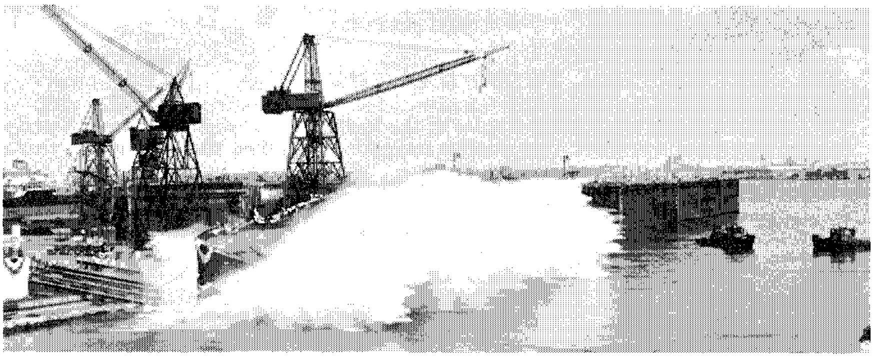
Andersen, Nellie T.
Barstow, Elmer M.
Bradley, Mabel D.
Brockhurst, Robert R.
Chute, Edward H.
Erlanger, George L.
Foley, Robert
Fraser, John G.
Hays, Earl E.
Hoadley, Lloyd D.
Howland, Myron P., Jr.
*Ketchum, David D.
Lyon, Thomas P.
Mavor, James W., Jr.
Michael, Joseph C., Jr.
Oliver, Isabel
Owen, David M.
Rainnie, William O., Jr.
Reese, Mabel M.
Richardson, William S.
Sawyer, Harold E.
Sharp, Arnold G.
Shodin, Leonard F.
Shultz, William S.
Snyder, Robert M.
Stanbrough, Jess H.
Stimson, Paul B.
Swinhart, Orrin L.
Walden, Robert G.
Walsh, Joseph B., Jr.
Wilkins, Charles H.

BIOLOGY

Bartlett, Martin R.
Baylor, Edward R.
Chadwick, Constance W.
*Clarke, George L.
Conover, Robert J.
*Conover, Shirley M.
Corwin, Nathaniel
*Fraser, Grace C.
Grice, George D., Jr.
Guillard, Robert R. L.
Hampson, George R.
Hessler, Robert R.
Hulburt, Edward M.
Kahler, Yolande A.
Kanwisher, John W.
Kuenzler, Edward J.
Mather, Frank J., III
McGill, David A.
Mogardo, Juanita A.
Renshaw, Thomas H.
Rogers, M. Dorothy
Ryther, John H.
Sanders, Howard L.
Scheltema, Rudolf S.
Schilling, John L.
Schroeder, William C.
Sears, Mary
*Sutcliffe, William H., Jr.
Teal, John M.
Turner, Harry J.
Vaccaro, Ralph F.
Watson, Margaret E.
Watson, Stanley W.
Wilson, Esther N.
Yentsch, Anne E.
Yentsch, Charles S.

CHEMISTRY AND GEOLOGY

*Aagard, Per
Athearn, William D.
Blumer, Max
Bowen, Vaughan T.
Caron, Henri L.
Clarner, John P.
Fitzgerald, William F.
*Giese, Graham S.
Hayes, Carlyle R.
McCormack, Eileen M.
Merrill, Emily B.
Morris, Robert E.
Pratt, Richard M.
Sachs, Peter L.
Siegel, Alvin
*Sugihara, Thomas T.
Tasha, Herman J.
Zeigler, John M.



Launching of ATLANTIS II — splash!

GEOPHYSICS

Backus, Richard H.
Baxter, Lincoln II
Bergstrom, Stanley W.
Bowin, Carl O.
Broadbent, Alice G.
Broughton, Jane F.
Bunce, Elizabeth T.
Cain, Henry A.
Carter, Alwyn L.
Caulfield, David D.
Dimock, Alan D.
Dow, Willard
Dunkle, William M., Jr.
Fahlquist, Davis A.
Foster, Donald B.
Gallagher, Gloria S.
*Graham, Helen S.
Graham, John W.
Grant, Carlton W., Jr.
Hays, Helen C.
Hersey, John B.
Hess, Frederick R.
Johnson, Diane C.
Johnston, Alexander T.
Knott, Sydney T., Jr.
Mellor, Florence K.
Mizula, Joseph W.
Morehouse, Clayton B.
Nalwalk, Andrew J.
Ostiguy, Betty P.
Poole, Stanley E.
Reitzel, John S.
Riegel, Richard E., Jr.
*Roberts, Helen M.
*Schevill, William E.
Senefelder, Lynne
Stetson, Thomas R.
Stillman, Stephen L.
Sutcliffe, Thomas O. L.
Vine, Allyn C.
Watkins, William A.
Wilharm, Larry
Wing, Asa S.
Witzell, Warren E.

PHYSICAL OCEANOGRAPHY

Allen, Ethel B.
*Arons, Arnold B.
Barbour, Rose L.
Barrett, Joseph R., Jr.
Bradshaw, Alvin L.
Bruce, John G., Jr.
Bumpus, Dean F.
Chandler, Richard A.
Chase, Joseph
Day, C. Godfrey
Densmore, C. Dana
Frank, Winifred H.
Fuglister, Frederick C.
Gifford, James E.
Hays, Betty C.
Houston, Leo C.
Metcalf, William G.
Miller, Arthur R.
Munns, Robert G.
Parker, Charles E.
Phillips, Helen F.
Randall, Vivian H.
Schleicher, Karl E.
Schroeder, Elizabeth H.
Soderland, Eloise M.
Stalcup, Marvel C.
Turner, Mary A.
Volkmann, Gordon H.
Voorhis, Arthur D.
Webster, T. Ferris
Whitney, Geoffrey G., Jr.
Worthington, L. Valentine

THEORETICAL OCEANOGRAPHY AND METEOROLOGY

Blanchard, Duncan C.
Bunker, Andrew F.
Chaffee, Margaret A.
Faller, Alan J.
Frazel, Robert E.
Kraus, Eric B.
Lee, Beverly M.
Levine, Joseph
Ronne, F. Claude
Saunders, Peter M.
Spencer, Allard T.
Stern, Melvin E.
Stevens, Raymond G.
Veronis, George
Webster, Jacqueline H.
Woodcock, Alfred H.

PERSONNEL

Supporting Services

The following were in the employ of the Institution for the twelve-month period ending December 31, 1962 (an asterisk indicating part-time throughout the year):

ADMINISTRATIVE AND SERVICE PERSONNEL

Allen, Norman T.
Anders, Wilbur J.
Andrews, George
Backus, Harold
Backus, Jeanne
Bard, Wallace R.
Behrens, Henry G.
Blomberg, Lennert
Bodman, Ralph H.
Bowman, Warren O.
Bryant, Edwin T.
Bujalski, Cleone C.
Cabral, John P.
Carlson, Alfred G.
Carlson, Eric B.
Carlson, Ruth H. E.
Chalmers, Agnes C.
Christian, John A.
Condon, John W.
*Cook, Harold R.
Corey, Norman
Crocker, Marion W.
Day, Joseph V.
dePunte, C. Michael
Dimmock, Richard H.
Eldridge, Stanley N.
Ferguson, Sandra K.
Ferris, George A.
Fielden, Frederick E.
Fisher, Stanley O.
*Fuglister, Cecelia B.
Gallagher, William F.
Gaskell, Fred
*Geggatt, Edward F.
Graham, Russell G.
Grant, Carlton, Sr.
Gregory, Howard F.
Hahn, Jan
Hatzikon, Kaleroy L.
Henderson, Arthur T.
Hodgkins, Harry L.
Hodgson, Sloat F.
Hunt, Otis E.
Innis, Charles S., Jr.
Jenkins, Delmar R.
Johnson, Harold W.
Lane, Egbert B.
LeBlanc, Donald F.
MacKillop, Harvey
McGilvray, Mary K.
McHardie, James
Minot, Mary K.
Mitchell, James R.
Morrison, Kenneth
Motta, Joseph C.
Orr, Elizabeth D.
Ortolani, Mary
Pasley, Gale G., Jr.
Patterson, John E.
Pimental, John M.
Prostredny, Evelyn
Reis, Janice
Rogers, Henry A., Jr.
Rossby, Harriet A.
Rudden, Robert D., Jr.
Scott, David D.
Simons, Cecelia
Slabaugh, Luther V.
Solberg, Otto
Souza, Thomas A.
Spooner, Charles E.
Stansfield, Richard
Stimpson, John W.
*Sullivan, James R.
Tometich, Louis J.
Veeder, Ronald A.
von Dannenberg, Carl R.
Walker, Jean D.
Watson, L. Hoyt
Weeks, Robert G.
Wing, Carleton R.
Woodward, Fred C., Jr.
Woodward, Ruth F.
Wright, Hollis F.

MARINE PERSONNEL

Backus, Cyril
Barabe, Ronald E.
Bazner, Kenneth E.
Betterly, Robert
Botas, Walter D.
Brown, Joseph C.
Bumer, John Q.
Byron, Paul C.
Cabral, John V.
Cahoon, Geraldine B.
Carter, Richard J.
Casiles, David F.
Cavanaugh, James J.
Clarkin, William H.
Colburn, Arthur D., Jr.
Cook, Alden H.
Cook, Hans
Copestick, Louis B.
Cotter, Jerome M.
Coughlin, Brooks W.
Crocker, John D.
Crouse, Porter A.
Davis, Charles A.
Davis, Peter
Edwards, Richard S.
Ewing, William R., Jr.
Gingrass, Norman
Halpin, William T.
Hiller, Emerson H.
Howe, Paul M.
Howland, Paul C.
Jefferson, Albert C.
John, Alfred C.
Karram, Calvin D.
Kellner, Paul D.
Kostrzewa, John A.
Lambert, Joseph L.
Leiby, Jonathan
Mackey, Malcolm R.
Matthews, Francis S.
Moller, Donald A.
Mysona, Eugene J.
O'Brien, Richard J.
Palmieri, Michael, Jr.
Pennypacker, Thomas R.
Pierce, George E.
Pierce, Samuel F.
Pike, John F.
Price, Don L.
Ribeiro, Joseph
Rose, Lawrence
Roy, Alfred J.
Seibert, Harry H.
Shields, William J.
Silverman, Maxwell
Stires, Ronald K.
Swinhart, Orrin L.
Thurston, Theodore G.
White, William A.
Williams, George A.
Williamson, Harvey V.

GRANTS AND FELLOWSHIPS

The following persons were awarded grants or fellowships during 1962:

BARBARA ALEXANDER
Reed College

EVELYN ALIFERIS
University of Massachusetts

NEIL R. ANDERSEN
Massachusetts Institute of Technology

PHILIP L. BALLARD
University of Michigan

ROGER W. BACHMANN
University of Michigan

PETER J. BRYANT
Emmanuel College, Cambridge, England

FRANCIS G. CAREY
Harvard University

CHARLES H. COPELAND
University of Alabama

SUSAN DEROPP
Cornell University

ARNT ELIASEN
University of Oslo, Norway

GEORGE FIELD
Princeton University

VINCENT P. FLANAGAN
University of Cambridge, England

LOIS FLEISCHER
Allegheny College

MICHAEL GARSTANG
Florida State University

GRAHAM S. GIESE
University of Rhode Island

PHILIP HALICKI
University of Kansas

OLGA HARTMAN
University of Southern California

JOHAN A. HELLEBUST
University of Toronto

PETER HERRING
Jesus College, Cambridge, England

RAYMOND HIDE
Massachusetts Institute of Technology

JAMES R. HOLTON
Massachusetts Institute of Technology

HARTLEY HOSKINS
University of Chicago

DAVID S. HIRSCHFELD
Harvard University

JOEL A. HUBERMAN
Harvard University

HIDEO KAWAI
Tôhoku Regional Fisheries Research Laboratory, Japan

ROBERT H. KRAICHNAN

WILLEM V. R. MALKUS
University of California at Los Angeles

LEON MESTEL
Trinity College, Cambridge, England

ERIC L. MILLS
Yale University

ERIK MOLLO-CHRISTENSEN
Massachusetts Institute of Technology

DEREK W. MOORE
Bristol University, England

ALVIN NASON
Columbia University

NORMAN S. NEIDELL
Imperial College, London, England

JEAN M. NOEL
California Institute of Technology

JOSEPH PEDLOSKY
Massachusetts Institute of Technology

DONALD C. RHOADS
State University of Iowa

ALLAN R. ROBINSON
Harvard University

ROBERT ROCKWELL
University of Massachusetts

CLAES ROOTH
University of Stockholm, Sweden

H. T. ROSSBY
Royal Technical University, Stockholm, Sweden

SAMUEL SAVIN
California Institute of Technology

BERT I. SHAPIRO
Institut d'Astrophysique, Paris, France

PIERRE SOUFFRIN
Swarthmore College

EDWARD A. SPIEGEL
Institute of Mathematical Sciences, New York

JOHN H. STEELE
Marine Laboratory, Aberdeen, Scotland

ALLAR TOOMRE
Massachusetts Institute of Technology

JOHN STEWART TURNER
Commonwealth Scientific and Industrial Research Organization, Australia

JOHN T. WASSON
Air Force Cambridge Research Center

BRUCE A. WARREN
Massachusetts Institute of Technology

RICHARD B. WILLIAMS
Harvard University

ROGER T. WILLIAMS
University of California at Los Angeles

JOHN WINCHESTER
Massachusetts Institute of Technology

W. REDWOOD WRIGHT
University of Rhode Island

PUBLICATIONS

During 1962, ninety-six papers bearing contribution numbers were published. See *Author, Subject-Locality, Taxonomic Index* published in 1957 for a complete list through 1956 and subsequent annual reports for the publications appearing since 1956. These are also listed in the back of the annual volume of *Collected Reprints.*

No. 925. CHARLES S. YENTSCH. Marine Plankton. In: Physiology and Biochemistry of Algae. Ralph A. Lewin, Edit., Academic Press, New York and London, pp. 771-797. 1962.

No. 1071. ROBERT R. L. GUILLARD. Salt and Osmotic Balance. In: Physiology and Biochemistry of Algae. Ralph A. Lewin, Edit., Academic Press, New York and London, pp. 529-540. 1962.

No. 1098. DAVID A. MCGILL. A Preliminary Study of the Oxygen and Phosphate Distribution in the Mediterranean Sea. *Deep-Sea Res.,* 8 (3-4): 259-269. 1962.

No. 1133. R. F. VACCARO. The Oxidation of Ammonia in Sea Water. *J. du Conseil,* Vol. 27, No. 1, pp. 3-14. 1962.

No. 1140. ROBERT R. L. GUILLARD and JOHN H. RYTHER. Studies of Marine Planktonic Diatoms. I. *Cyclotella nana* Hustedt and *Detonula confervacea* (Cleve) Gran. *Canadian J. Microbiol.,* Vol. 8, pp. 229-239. 1962.

No. 1141. JOHN H. RYTHER and ROBERT R. L. GUILLARD. Studies of Marine Planktonic Diatoms. II. Use of *Cyclotella nana* Hustedt for Assays of Vitamin B_{12} in Seawater. *Canadian J. Microbiol.,* Vol. 8, pp. 437-453. 1962.

No. 1142. JOHN H. RYTHER and ROBERT R. L. GUILLARD. Studies of Marine Planktonic Diatoms. III. Some Effects of Temperature on Respiration of Five Species. *Canadian J. Microbiol.,* Vol. 8, pp. 447-453. 1962.

No. 1143. RUDOLF S. SCHELTEMA. Pelagic Larvae of New England Intertidal Gastropods. 1. *Nassarius obsoletus* Say and *Nassarius vibrex* Say. *Trans. Amer. Microsc. Soc.,* Vol. 81, No. 1, pp. 1-11, 1962.

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No. 1162. W. E. SCHEVILL, R. H. BACKUS and J. B. HERSEY. Sound Production by Marine Animals. In: The Sea, M. N. Hill, Edit., Vol. 1, Physical Oceanography, Interscience Publishers, New York and London, pp. 540-566. 1962. (Not included in *Collected Reprints*).

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TREASURER'S REPORT

The accounts for the year 1962 have been audited by Lybrand, Ross Bros. & Montgomery.

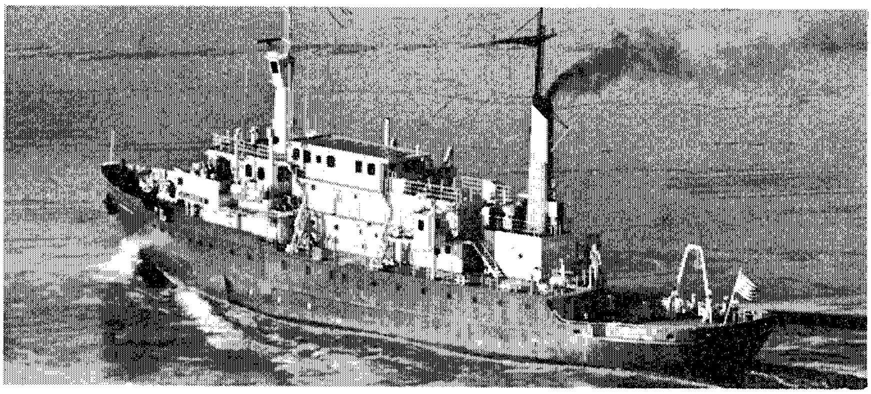
The book value of endowment funds at December 31, 1962, was $3,710,160, of which $1,234,403 represented accumulated net gains from sales of investments. The market value of endowment assets on the same date, including real estate at book amount, was $5,812,657. Endowment fund investments and income received therefrom are summarized in Schedule C.

The plant fund accounts on the Balance Sheet reflect the changes during the year resulting from the construction on the new research vessel and the new Laboratory of Marine Sciences; and the acquisition and renovation of the Research Vessel Gosnold, as well as the usual addition to the plant reserve funds resulting from depreciation accruals and write-offs of deferred charges.

Income received on endowment assets was $191,875 for the year ended December 31, 1962, compared with $190,208 the previous year. Included in endowment income is $1,589 of parking lot income, which represented a 5 per cent return on this investment. The balance of the parking lot income, amounting to $559, was transferred to endowment assets, to amortize the costs of this property. A loss of $1,622 on 38 Water Street property incurred during the year was charged against endowment income. Endowment income represented a return on endowment fund assets of 3.3 per cent at year-end market quotation, 5.2 per cent on book amount and 7.8 per cent on the contributed amount of the endowment fund.

Endowment income was allocated for 1962 operating expenses at the rate of 6 per cent of the book amount of original endowment funds, or $146,677. Of the balance of endowment income, $45,198, there was transferred to the income and salary stabilization reserve $44,081 and to Oceanographic Associates as income from investment of life memberships, $1,117.

The Institution's 1962 contribution to the Woods Hole Oceanographic Institution's Employees Retirement Trust amounted to $124,243. The trust is administered by three trustees. Most of the old Retirement Fund has been paid in the form of annuities to the participating members. The remaining cash was paid to participating members in January 1963.



ATLANTIS II - trials.

LYBRAND, ROSS BROS. & MONTGOMERY
ACCOUNTANTS AND AUDITORS

COOPERS & LYBRAND
IN AREAS OF THE WORLD
OUTSIDE THE UNITED STATES

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

We have examined the balance sheet of Woods Hole Oceanographic Institution as at December 31, 1962 and the related statements of operating expenses and income and of changes in funds for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances. It was not practicable to confirm receivables from United States Government departments, but we have satisfied ourselves as to such accounts by means of other auditing procedures.

In our opinion, the accompanying statements present fairly the financial position of Woods Hole Oceanographic Institution at December 31, 1962 and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

Boston, Massachusetts
March 14, 1963

Lybrand, Ross Bros & Montgomery

BALANCE SHEET

As at December 31, 1962

ASSETS

ENDOWMENT FUND ASSETS:		
Investments (Schedule C):		
Bonds (market quotations $2,012,353)		$ 2,042,815
Stocks (market quotations $3,702,342)		1,569,383
Real estate		91,101
		3,703,299
Cash		6,861
		3,710,160
PLANT FUND ASSETS (Note):		
Laboratory plant and equipment		941,760
Vessels and equipment		5,096,154
Other property		302,041
Laboratory under construction		571,005
Total plant		6,910,960
Expenditure in anticipation of funds		780,815
Current funds advanced to plant		(246,065)
		7,445,710
CURRENT FUND ASSETS:		
Cash		98,957
Time deposit		50,000
Accounts receivable:		
U.S. Government	$1,004,090	
Other	24,778	1,028,868
Unbilled costs:		
U.S. Government	1,294,198	
Other	9,623	1,303,821
Supplies inventories		40,954
Deferred charges		38,377
Current funds advanced to plant		246,065
		2,807,042
		$13,962,912

NOTE — Since 1945 the Institution has provided for depreciation of plant assets other than vessels at annual rates of 2% on buildings and 5% to 33⅓% on equipment, carrying the amounts to general plant and equipment reserve.

BALANCE SHEET

As at December 31, 1962

LIABILITIES

Endowment Funds:		
Unrestricted as to income	$2,000,000	
Unrestricted as to principal and income	54,337	$ 2,054,337
For upkeep of plant		419,420
Henry Bryant Bigelow Chair of Oceanography		2,000
Accumulated net gain on sales of investments		1,234,403
		3,710,160
Plant Funds:		
Invested in plant (including $4,330,000 for construction of Atlantis II, title to which is conditional upon its continued use for oceanographic research)		6,910,960
Unexpended:		
Fund for construction of a new laboratory		367,725
Fund for acquisition of capital assets		128,770
General plant and equipment reserve		21,406
Fund for construction of a small vessel		16,849
		7,445,710
Current Liabilities and Funds:		
Notes payable to bank		500,000
Accounts payable and accrued expenses		862,490
Contribution payable to employees' retirement plan and trust		124,243
Unexpended balances of gifts and grants for research:		
Government	578,241	
Other	225,698	803,939
Reserves:		
Income and salary stabilization reserve	398,522	
Working capital and contingency reserve	117,848	516,370
		2,807,042
		$13,962,912

COMPARATIVE STATEMENT OF OPERATING EXPENSES AND INCOME

Years Ended December 31, 1962 and 1961

	1962	1961
OPERATING COSTS AND PROVISIONS:		
Direct costs of research activity (Schedule A):		
Salaries and wages	$1,689,864	$1,404,702
Vessel operations	1,238,568	1,230,257
Materials and services	3,282,433	1,628,565
Travel	217,087	116,373
	6,427,952	4,379,897
Indirect costs:		
General and administration (Schedule B)	741,459	801,366
Plant operations (Schedule B)	315,532	277,578
Miscellaneous	27,040	6,526
Other charges:		
Provision for working capital and contingencies	88,696	25,487
Plant additions, books and equipment	32,487	43,799
	7,633,166	5,534,653
INCOME:		
For sponsored research (including 1962 — $1,937,515, 1961 — $1,027,309 gifts and grants expended):		
For direct costs	6,335,490	4,284,949
For indirect costs	954,726	952,316
Fees for use of facilities	189,580	144,236
	7,479,796	5,381,501
Endowment income availed of:		
For institution research	92,462	94,948
For institution indirect costs	54,215	51,314
Miscellaneous	6,693	6,890
	$7,633,166	$5,534,653

STATEMENT OF CHANGES IN FUNDS

For the Year Ended December 31, 1962

	Endowment Funds	Plant Funds: Invested in Plant	Plant Funds: Unexpended	Unexpended Balances of Gifts and Grants for Research (Note)	Reserves: Income and Salary Stabilization Reserve	Reserves: Working Capital and Contingency Reserve
BALANCE, December 31, 1961	$3,549,925	$2,171,017	$ 821,282	$ 523,383	$354,441	$ 29,152
Gifts and grants received	12,177		3,568,000*	2,300,976		
Endowment income					191,875	
Net gain on sales of investments	148,058					
Additions from current year's operations:						
Books and equipment purchased		32,487				
Provision for depreciation			93,842			
Provision for working capital, deferred maintenance, and contingencies						88,696
Availed of for research costs				(1,937,515)	(146,677)	
Transferred to unexpended balance of gifts from Oceanographic Associates				1,117	(1,117)	
Invested in plant		4,727,504	(4,727,504)			
Cost of assets disposed of		(20,048)				
Miscellaneous (reductions)			(1,685)	(84,022)		
BALANCE, December 31, 1962	$3,710,160	$6,910,960	($ 246,065)	$ 803,939	$398,522	$117,848

*Includes $2,700,000 received on grant for design and construction of a research vessel and $868,000 for construction of a laboratory building.

NOTE — Unexpended balances consist of amounts received in advance of expenditure, and do not include receipts or expenditures under reimbursement type contracts.

Schedule A

DIRECT COSTS OF RESEARCH ACTIVITY

For the Year Ended December 31, 1962

	Salaries and Wages	Vessel Operations	Materials and Services	Travel	Total
U. S. GOVERNMENT:					
Contracts	$1,166,601	$1,049,871	$2,302,680	$108,951	$4,628,103
Grants	487,659	175,456	889,333	96,747	1,649,195
OTHER SPONSORED RESEARCH	6,013	1,448	45,330	5,401	58,192
Total direct costs of sponsored research	1,660,273	1,226,775	3,237,343	211,099	6,335,490
INSTITUTION RESEARCH	29,591	11,793	45,090	5,988	92,462
Total direct costs of research	$1,689,864*	$1,238,568*	$3,282,433**	$217,087	$6,427,952

*Includes contribution to retirement plan ($100,849) and social security taxes ($49,826) which were classified as general expenses in prior years.

**Includes grants and fellowships:

U. S. Government contracts	$25,480
Other sponsored research	29,902
Institution research	31,795
	$87,177

Schedule B

GENERAL AND ADMINISTRATION EXPENSES AND EXPENSES FOR PLANT OPERATION

For the Year Ended December 31, 1962

GENERAL AND ADMINISTRATION

GENERAL EXPENSES:		
Staff benefits:		
Contributions to retirement plan		$ 15,714
Social security taxes		7,060
Employee health benefits		27,535
Group insurance		7,588
		57,897
Shop services		147,800
Housing, net		8,000
ADMINISTRATION EXPENSES:		
Salaries and wages	$314,712	
Insurance, travel, supplies and other	213,050	527,762
		$741,459

PLANT OPERATION

Salaries and wages		$ 70,628
Contribution to retirement plan		3,392
Social security taxes		1,978
Provision for depreciation (credited to general plant and equipment reserve)		76,440
Other repair costs	$78,088	
Heat, light and power	34,906	
Other	50,100	163,094
		$315,532

NOTE — In 1962 the Institution allocated contributions to retirement plan and social security taxes as a direct cost to the applicable contracts and grants, other sponsored research, Institution research, general and administration, and plant operations, resulting in a decrease in general and administration expenses of $158,070.

Schedule C

SUMMARY OF INVESTMENTS

As at December 31, 1962

	Book Amount	% of Total	Market Quotation	% of Total	Endowment Income
BONDS:					
Government	$ 695,584	18.78	$ 700,175	12.06	$ 18,228
Railroad	385,133	10.40	362,410	6.24	16,921
Public utility	354,357	9.57	343,730	5.92	15,328
Industrial	435,162	11.75	430,213	7.41	18,436
Financial and investment	172,579	4.66	175,825	3.03	8,966
Total bonds	2,042,815	55.16	2,012,353	34.66	77,879
STOCKS:					
Preferred	259,746	7.01	260,175	4.48	12,500
Common:					
Public utility	330,721	8.93	1,104,542	19.02	30,280
Industrial	665,276	17.97	1,753,288	30.20	52,927
Miscellaneous	313,640	8.47	584,337	10.07	18,322
Total common stocks	1,309,637	35.37	3,442,167	59.29	101,529
Total stocks	1,569,383	42.38	3,702,342	63.77	114,029
REAL ESTATE	91,101	2.46	91,101*	1.57	(33)
Total investments	$3,703,299	100.00	$5,805,796	100.00	$191,875

*At book amount.