Woods Hole

Oceanographic

Institution

Woods Hole, Massachusetts

1963

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Director's Report

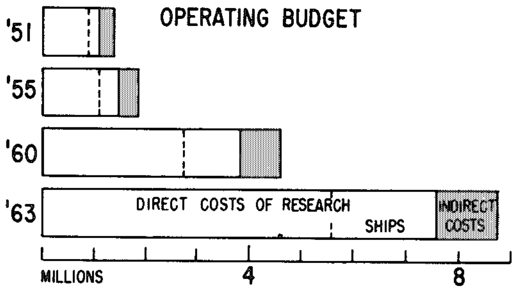
The reporting of our scientific accomplishments and technical trends in concise and readable form becomes more and more difficult as the volume of our work grows and as its content becomes more complex. There have been many interesting results this year but we cannot report adequately on all of them in this Annual Report. In following sections each of our Department Chairmen outlines the current scientific work in his department. In addition a more complete digest of our work may be found in the Summary of Investigations for 1963 which has been prepared as a separate volume to supplement the information in this Report. One must, of course, turn to the published papers for a complete description of the work and the results obtained. The major scientific output of the Institution continues to be the publications in scientific journals. During 1963, one hundred twelve articles and papers have been assigned WHOI Contribution Numbers and published; they are listed later in this Report. Since the Institution's founding, more than 1300 published articles have carried our Contribution Number.

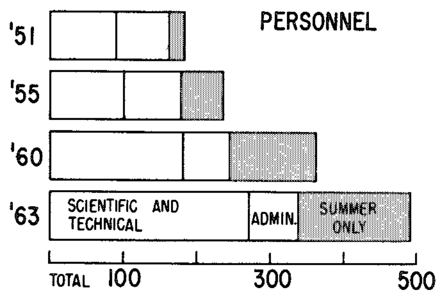
A number of significant steps of long-term importance affecting the Institution as a whole have been taken this year. Among these are the development of new appointment policies, the establishment of tenure, the growth of our educational activities and the continued improvement of our research facilities.

The development of new appointment policies which include a new system of titles and tenure has been in process for several years. Many individuals from the staff and the Board of Trustees have contributed to their evolution. By the end of the year the final policy statement had been distributed to the Trustees. It was approved and established as Institution policy at the meeting of the Board on January 9, 1964.

The establishment of a formal tenure policy was desirable for many reasons. Our close associations with the academic world, the necessity to compete with universities for the best scientists, the protection tenure provides the individual from arbitrary decisions, the security tenure implies and the faith we thereby demonstrate in the sound future of the Institution — all these reasons justified the adoption of a well defined tenure policy. The provision of tenure necessitated the introduction of a more formal system of titles and appointments; the new titles have been used throughout this Report.

Our annual budget has again increased. The total operating costs for this year were $8.7 million, compared with $7.6 million in 1962. The increase was



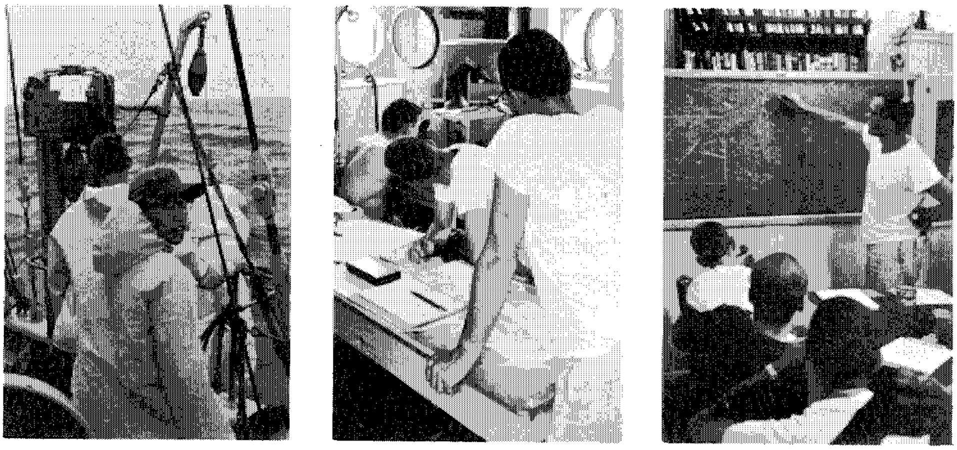


almost wholly in direct costs of research activities, as indirect costs increased only very slightly over last year. In spite of the economy moves initiated in Washington late in the year, we expect another modest increase in the budget for 1964.

To a large extent the funds received from Federal agencies are committed to activities that have been described in formal research proposals. Frequently however, new possibilities for fruitful research appear unexpectedly, and our ability to explore these new possibilities is dependent in the first instance on the private funds of the Institution. Our private funds come from several sources; endowment income, gifts and bequests, foundation grants, and from the Woods Hole Oceanographic Associates. During the past year the Associates contributed more than $100,000 to the Institution; this was slightly more than one-fifth of the private funds available to us. The amount is particularly significant when it is realized that this sum is roughly equivalent to what might be expected in income from an additional endowment of two million dollars. The need for increased endowment has not lessened, but the Associates program has been of great assistance in filling a portion of this need.

The Associates have been generous not only in providing funds for activities which could not otherwise have been undertaken; they have also been generous with their time, energy and advice. They have shown a deep interest in the oceans and in our studies of them. They have peered over our shoulders to see how we were doing, expressing pleasure at our successes and sympathizing with our disappointments. They have willingly advised us on problems outside our range of experience. They have interested many people both young and old in oceanography and the Institution, thus strengthening the Institution both now and in the future. We are very grateful to our Associates for their many efforts in our behalf and are proud to have so many friends throughout the country.

The Scientific Visiting Committees again provided a critical review of our scientific departments, examining in particular the progress which had been made in implementing their recommendations of last year. We were pleased that they observed progress and equally pleased that they offered suggestions for additional improvements. We appreciate very much the very real concern for the Institution's well-being which the members of the Committees have shown.



School Ship: Summer students on ATLANTIS, crossing the Gulf Stream, making hydrographic stations, tracking deep Swallow floats in the upper laboratory and using the main saloon as a classroom.

Our educational activities took a great step forward this year with the initiation of three formal courses for college and graduate students which utilized the ATLANTIS as a training ship. Thirty-two students participated in these courses and each group spent about three weeks at sea on the ATLANTIS taking data and making observations. We are most enthusiastic about the courses and the eagerness demonstrated by the students and have submitted a proposal to the National Science Foundation for funds to provide the courses again in 1964.

Another new part of our educational program was the establishment of a $2000 Science Scholarship at the Lawrence High School in Falmouth. This was awarded for college work in science or engineering to a graduating senior selected by the High School faculty for his scholastic excellence. We hope to provide a similar scholarship in future years.

Our cooperative education program with three secondary schools in Rhode Island and Massachusetts again proved to be most rewarding, both for the students and for our staff members who participated.

This past year witnessed some significant additions to our facilities for carrying on research programs, the most impressive of which is the ATLANTIS II. She has performed most ably throughout the year and we all are extremely proud of her. After several shakedown cruises early in the year she participated in the search for the ill-fated submarine THRESHER, and in July sailed for the Indian Ocean. She returned to Woods Hole in December, having steamed more than 30,000 miles. The scientists on board made 227 hydrographic stations, 2454 bathythermograph lowerings, and daily meteorological observations in the Indian Ocean. She had no major malfunctions her first year and only a few minor ones, and in this regard set a high standard of comparison for other new research vessels, both domestic and foreign. We are quite convinced that the ATLANTIS II is the finest oceanographic research vessel afloat.

The new biology and chemistry building was very nearly completed in May when we began to take occupancy. The building also has been noticeably trouble-free and there have been only a few problems of getting the new laboratories and other equipment functioning properly.

We have made a significant step into the field of rapid data processing with the lease of a medium capacity, medium speed digital computer. The addition of a great deal of peripheral equipment has made it very flexible and well suited to our needs. The peripheral equipment allows the reading of data collected on many different types of recording media. By the end of the year the computer was running slightly more than one shift and it seems probable that within several years we shall need a computer of increased capacity.

The Navy has loaned the Institution a C-54Q aircraft (DC-4) to replace the R4D (DC-3) which we have operated in past years. The plane was completely overhauled and fitted out with scientific equipment before leaving in June on its first research flight to the Indian Ocean for six weeks. It later worked in the Caribbean for five weeks in conjunction with the CRAWFORD and a shore party on Barbados. We are very pleased with the plane and look forward to the new research areas that it opens for us.

Both the CHAIN and the GOSNOLD received special attention at the hands of the shipfitters this year. A combination hydrographic and trawl winch was installed on the GOSNOLD, thus completing our plans for her conversion to an oceanographic research vessel. A two-stage plan for the improvement of the CHAIN was developed to bring her up to the high standards of the ATLANTIS II. The first of these stages, including air-conditioning for work in the tropics, was completed during her annual shipyard period and it is planned to complete the second stage in 1964.

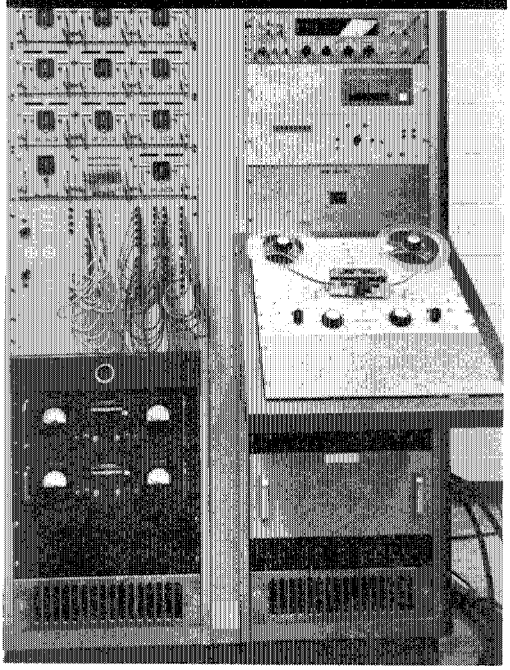
Although she served us well for a dozen years, the BEAR's advancing age, small size and noisy engines made her continued usefulness to us doubtful, and she was therefore sold.

Because of our close attachment for the seas and our desire to understand what is going on in them, we all were greatly dismayed to learn of the unexplained sinking of the submarine THRESHER in April. The ATLANTIS II was working in the Gulf of Maine, only seventy-five miles from the location of the sinking, and her services were immediately offered to the Navy to aid in the search. We were proud to have the equipment and the personnel capable of working in the deep water encountered, and the ATLANTIS II proved several times over that her design and construction leaves little to be desired for an oceanographic research vessel. She consistently worked in rougher seas than other research vessels on the scene and she stayed on station with no malfunctions of ship or equipment while other research vessels returned to port for repairs.

The International Indian Ocean Expedition was the major international oceanographic effort this year. As previously mentioned, the ATLANTIS II and the C-54Q were used by Institution scientists in their studies there, while other Institution scientists worked aboard the ANTON BRUUN operated for the national biological program in the Indian Ocean. A massive quantity of data has been collected and preliminary analyses have indicated many interesting facets of the Indian Ocean which will require further study in the years ahead.

department of applied oceanography

Earl E. Hays, Chairman



Analogue to Digital Data REduction System for Oceanographic Research especially designed at Woods Hole for reduction of multichannel oceanographic data.

Information Processing Center

The Recomp II computer, which had been at the Institution several years, was replaced in 1963 by a General Electric 225 computer. The new computer was installed temporarily in the Laboratory of Oceanography in April and was moved to the Laboratory for Marine Sciences in the latter part of June when that building became available. Additional equipment has subsequently been added to increase the capabilities of the system. The present configuration, built around an intermediate size computer by today's standards, is an extremely flexible system with respect to input and output data handling equipment. This is particularly desirable at present as most of the computer time is used in data handling rather than in mathematical computations, and the flexibility gives the scientist a choice of data format.

Personnel from all departments have been using the computer. Some examples of the special problems which were worked on are: reduction and analysis of current meter data, sediment size analysis, acoustic ray tracing, reduction of hydrographic station data and plankton abundance statistics. A large part of the efforts of the information processing center staff during the past year has been devoted to instructing Institution scientists in the techniques of programming, in the capabilities of the computer and peripheral equipment, and in the types of problems in which the computer might be of use to them. Usage of the computer increased steadily throughout the year, and by year-end the computer was operating slightly in excess of one full shift. At the present rate of increase, it will be operating on a multi-shift basis by the end of 1964 in its present configuration.

Deep Sea Buoys

During 1963 thirty-five moored current meter stations were set. Of these, twenty-seven were completely recovered, one completely recovered after going adrift, four partially recovered adrift, two partially recovered on station, and one completely lost.

Twenty-six of these stations were set as part of the EQUALANT I cruise. Two stations were set at the THRESHER site, three in Kane Basin in the Arctic, three near Bermuda, and one south of Cape Cod in deep water. Although the recovery rate for 1963 appears better than that of 1962, the mooring problem is not solved. Our goal is to set moorings that last more than six months in North Atlantic waters with a ninety per cent recovery factor. Plastic lines of different materials and different methods of construction were tried, as was armored nylon cable. At the end of the year a submerged float, steel wire system was being readied for test early in 1964.

Refinement of the design of the current meter and interpretation of the records received considerable attention during the year. The motion of the instrument on its mooring, both vertical and horizontal, influences the current record obtained. An experiment to investigate these effects was carried out at Bermuda in the fall. The surface buoy of an anchored station was tracked visually from land. The current records from the meters are now being compared with the observed motion of the buoy.

Data processing techniques have been improved during the year. Strobing the encoding lights and increasing the film transport speed have made automatic read-out more reliable. Programs have been written for the GE 225 computer for correlation studies of the data, for computing trajectories, and for developing elementary statistics.

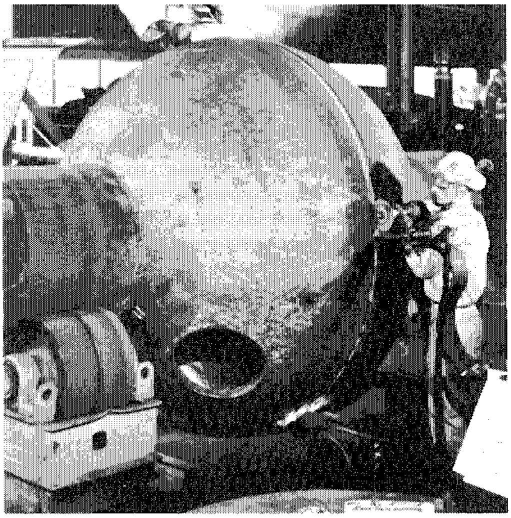
Mechanical Sound Source

The mechanical sound source which in operation will cause a metal slug to strike an anvil at high speed is being redesigned. The design of the radiating system for efficient transfer of impact energy to sonic energy has been completed and a new design of the driving mechanism is under way. The original design of the drive system was similar in principle to a crossbow, although the geometry was quite different. Detailed analyses of this design, however, indicated several technical problems that would have prevented the realization of the full potential of the system. The recent development of high energy forging machines that use "gas guns" as the driving devices has opened up another approach to the drive system that is now being investigated.

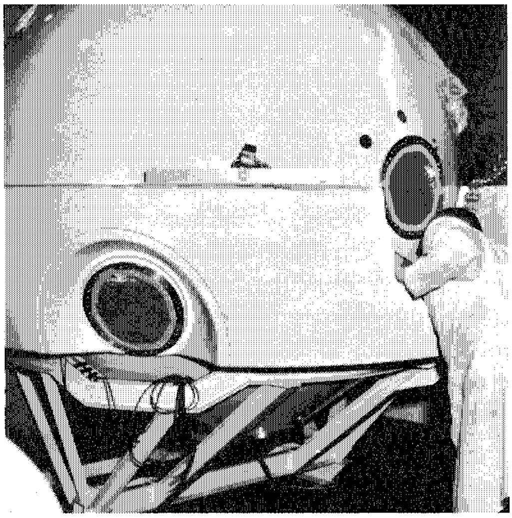
Acoustics and Optics

Information may be transmitted through sea water acoustically and optically; techniques for predicting and improving the reliability of information transmission by these means are therefore of some importance.

The prediction of acoustic transmission characteristics is based on sound velocity conditions in the area; the sound velocity profiles are derived from hydrographic station data. The CHAIN in 1961 made a series of hydrographic stations, velocimeter lowerings, and a long range sound transmission run in the eastern Mediterranean to test the effectiveness of the interpolation of hydrographic station data for



Welding equator seam of ALVIN's pressure hull.



Hull mounted in frame and middle forebody.

acoustic propagation. These data are being reanalyzed as inconsistencies have been discovered in the previous analyses.

A review of the literature on the optical properties of sea water in regard to scattering and polarization of light has given some promise that the sharpness and contrast of underwater photographs may be improved by proper use of spatial filtering. The deep submersible research vehicle expects to take many thousands of photographs and any improvement in their quality will be of great benefit.

Deep Submersible Research Vehicle

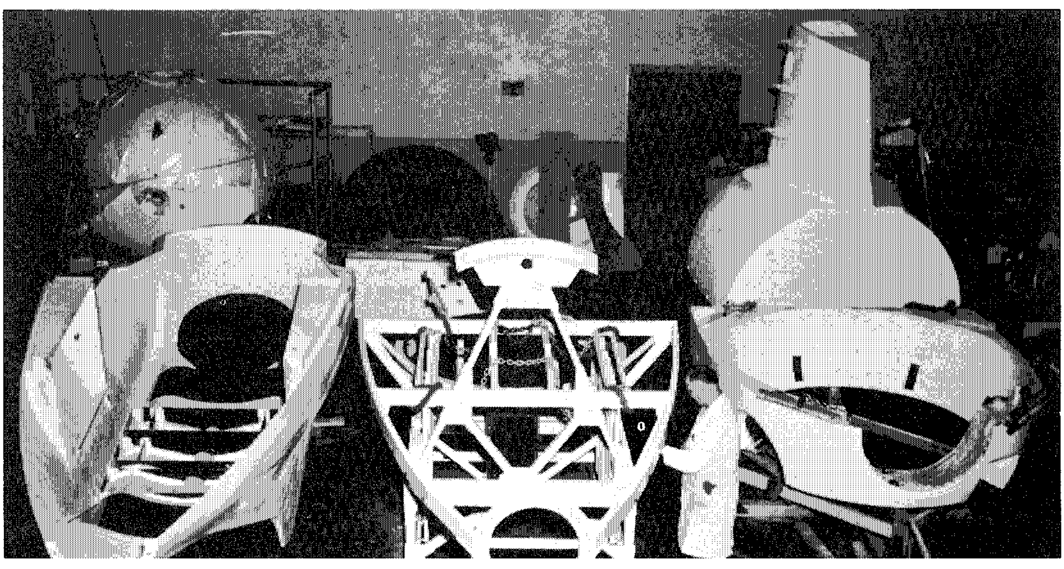
The construction of the two-man submersible designed for operating to depths as great as 6,000 feet has proceeded more slowly than planned. Although the contractor had promised delivery of ALVIN in the fall of 1963, it now appears that mid-1964 is more realistic.

Three pressure hulls have been constructed. The least perfect of these will be tested, hopefully to destruction, while the two better ones will be fitted with all pressure resistant components and tested to two thirds the collapse pressure of the first hull.

Instrumentation and support equipment for the craft have been specified and purchased. These include a continuous frequency modulated scanning sonar, echo sounders, underwater telephone, a doppler navigating system, lights, cameras, a mechanical arm, battery and air charging equipment, and maintenance facilities.

A catamaran barge for handling ALVIN at sea was being designed at year end. The design will utilize two hulls, each

ALVIN's major hull components



ninety-six feet long by a fourteen-foot beam, which have been made available to us by the Navy. Model tests have been made with a tentative design and were satisfactory. With the hulls already completed, the catamaran offers an economical approach to the handling problem.

Very Low Frequency Navigation

If a phase comparison is made of the output from two perfect oscillators, one stationary and the other moving, a change in phase difference is simply related to the change in separation between the two oscillators and circles about the stationary oscillator can be related to the phase difference. Two stationary oscillators and one moving oscillator can be used to generate intersecting circles, or as is known in navigational terms, a "fix." Certain low frequency transmitting stations operating in the frequency range of twelve to twenty-five kilocycles maintain their frequency with a stability that makes navigation by this method attractive, and studies were made this year to determine the feasibility of utilizing these stations in a navigational system.

A suitable oscillator and phase sensitive receivers were installed aboard the ATLANTIS for tests in New England waters, and later aboard ATLANTIS II for the entire Indian Ocean cruise. As was expected, the system as used was not a highly accurate one, but over much of the track it gave positions to within a few miles of the real track. Useful information was available about the drift while on station and the possibility of developing a world-wide navigation system was investigated. It was possible to compensate for the drift of the local oscillator, but changes in the propagation path due to ionospheric changes were not so easy to handle. The ionization of the upper atmosphere changes the phase velocity of the waves and therefore wave length, which gives a different scale factor for plotting the phase differences. This effect is quite consistent in any one area, but must be determined in that area. For effective use of this system, data must be collected on this diurnal effect much as they have been collected on tides. Propagation from some stations which were monitored at distances of eight to nine thousand miles was very interesting. The wave propagation direction changed by 180 degrees indicating that the wave traveling the shortest path was not always dominant.

Telemetry and Instrumentation

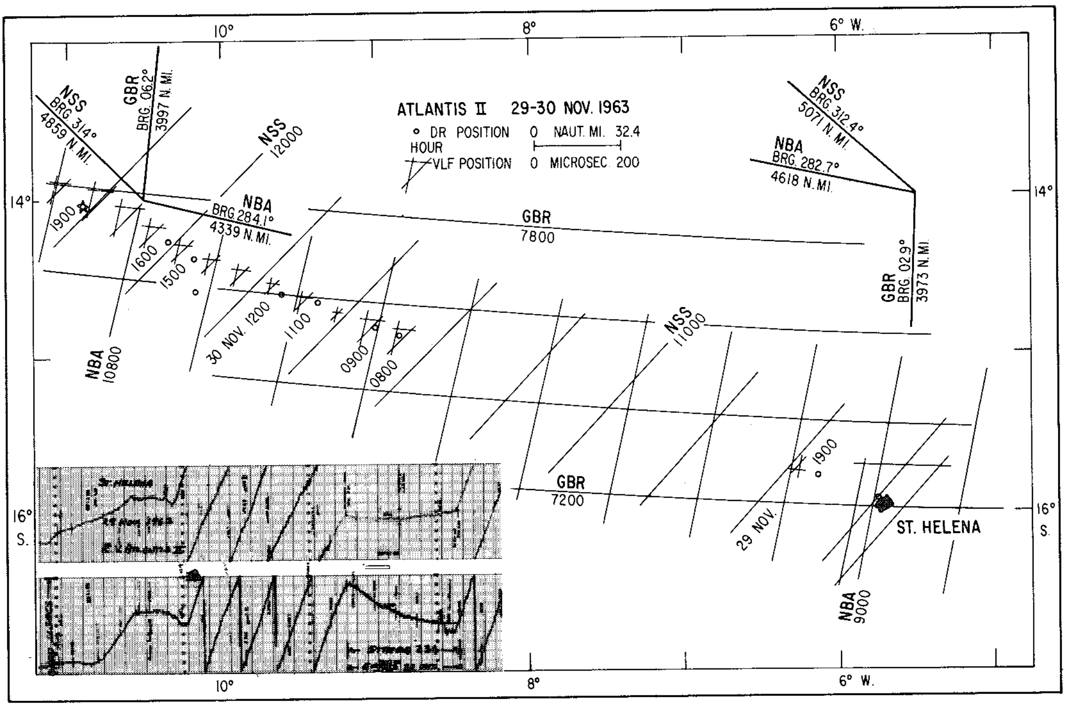
The telemetry of current and temperature data from buoys at sea can now be accomplished in a satisfactory manner with respect to the coding of the information, the transmission, reception, decoding and recording in a format that may be put directly into the computer. Experiments performed in 1963 were successful in this aspect. The system is expected to change but does meet the present requirements in terms of cost and reliability. This information gathering and handling is not independent of the mooring problem, however, and work has progressed in such a way as to reduce the mooring loss problem.

A buoy with a bright flashing light is not too difficult to find at night from a ship or aircraft, but the high rate of energy consumption is difficult to supply for buoys that are to be at sea for many months. Drifting buoys are often monitored by aircraft, and for this use a high frequency radio pulse is as effective as a light, gives longer ranges, and works in the daytime. Units that respond to radar pulses by flashing a light or by transmitting high frequency pulses have been developed and tested at sea. These units act only as receivers until triggered by a radar pulse and have low power consumption.

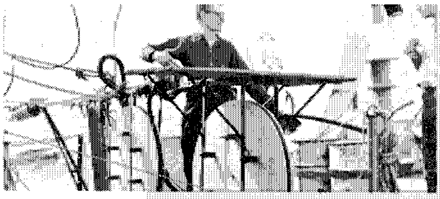
Moorings that are made with plastic line must have conducting leads in addition to the mooring line if data are to be telemetered to shore. As the "fishbite" problem of the plastic lines has not been solved, an investigation was made into the use of a single insulated wire mooring cable. It appears feasible to couple instruments to this cable magnetically and to use the wire as the information cable. An experiment has been planned using such a cable with a submerged float as the main buoyancy chamber and a small surface float for the antenna. This offers the additional advantage of placing the largest portion of the buoyancy beneath the wave action, thus reducing forces caused by large seas.

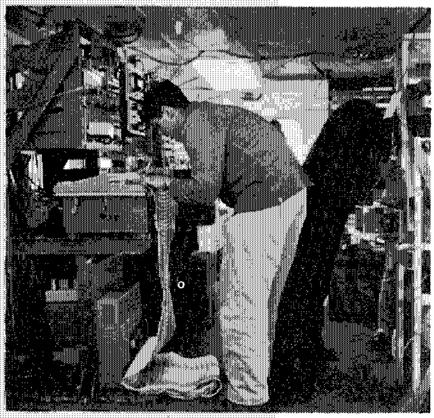
A system for the rapid scanning of a string of temperature sensors has been developed and is being applied to the thermistor chain as well as to moored buoys.

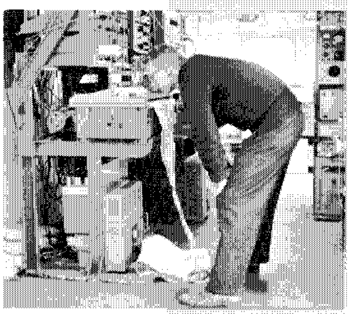
A system, originally developed for tracking drifting buoys, has been applied to moored buoys. The buoy receives Consolan signals and retransmits these signals to the data receiving system. Consolan is a low frequency navigating system which covers a good part of the North Atlantic. The signal received allows a line of position to be plotted; by receiving two stations the buoy position can be fixed within five miles. The position of a buoy can therefore be checked with regularity and any large motions detected. Those buoys that break loose, or are purposely drifting, can then be located with a minimum amount of searching. The major technical problem, which has now been solved, was the simultaneous use of the antenna for reception and transmission.

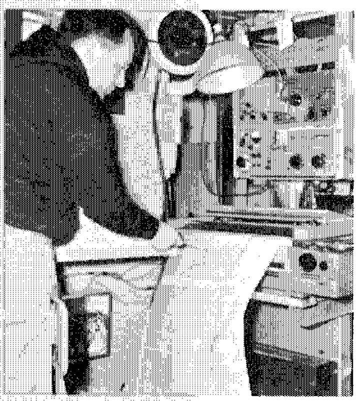


Relative Navigation using the transmissions of Very Low Frequency (VLF) Stations.
The traces shown result from the comparison of the phases of two VLF stations and a precision oscillator aboard ship. Each excursion of the traces is equivalent to 16.2 nautical miles which is plotted to obtain the geographical positions.

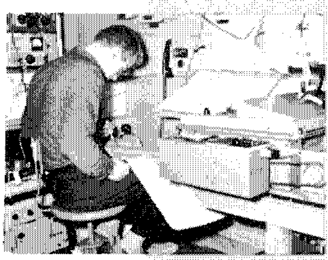


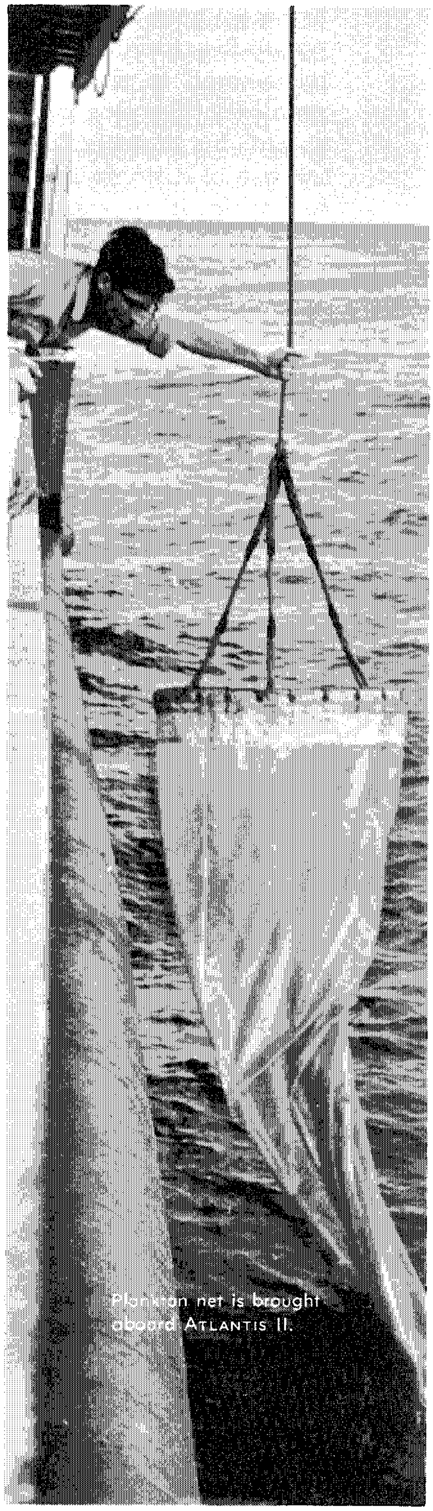






Continuous seismic profiling with "Boomer" as an acoustic source.



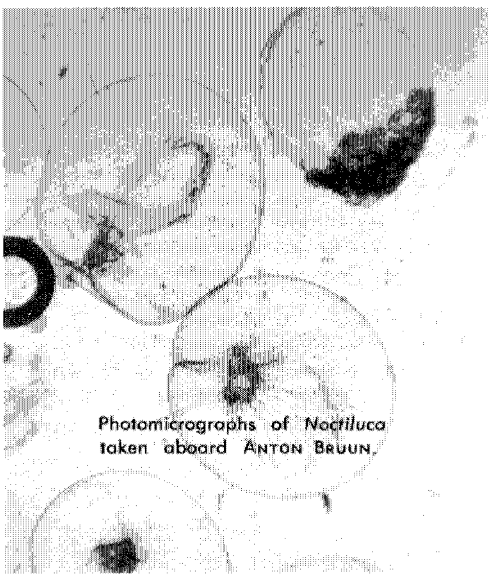


Plankton net is brought aboard ATLANTIS II.

department of biology

John H. Ryther, Chairman

Camera lucida drawings for taxonomic studies of new copepod species.



Photomicrographs of *Noctiluca* taken aboard ANTON BRUUN.

Dissolved and Particulate Organic Matter

Independently, and for a variety of reasons, several members of the biology staff were concerned this year with problems relating to the origin, distribution, chemical composition and fate of the dissolved and dead particulate (detrital) organic matter in the sea. At least part of the interest in this subject stems from the realization, obtained through preliminary investigations, that while the biomass of living organisms in the sea is equivalent to one-tenth or less the quantity of detritus and perhaps one-hundredth the mass of dissolved organic matter, the ecological role and significance of these substances are largely unknown.

An improved technique was developed for measuring both particulate and dissolved organic carbon more accurately and rapidly than previously possible. This method was employed on two short cruises in the North Atlantic, and in the Arabian Sea during one of the International Indian Ocean Expedition cruises of the ANTON BRUUN. As a result of the latter investigations, more data on this subject are available for that restricted part of the Indian Ocean than for the rest of the oceans combined. Although the results are still being analyzed, it appears that dissolved carbon is a surprisingly conservative property of sea water and may be useful as a water mass indicator.

Similarly, organic phosphorus, measured indirectly as the difference between total and inorganic phosphorus, shows promise as a tracer revealing the past history of a body of water. Less conservative than carbon, organic phosphorus is not normally detectable in deep water and, when found, indicates the presence of that water at the surface in the recent past. Sufficient measurements of organic phosphorus have now been made throughout the western North Atlantic to evaluate the usefulness of this parameter as an indicator of water masses and hence of deep circulation.

Meanwhile, experiments in the laboratory have contributed to our understanding of the origin and rate of production of organic compounds by living organisms. Rates of excretion of photoassimilated carbon were determined for twenty-two species of phytoplankton in culture and for natural populations from Vineyard Sound and the Gulf of Maine. In contrast to earlier reports, most of the algae excreted no more than three to six per cent of their photoassimilated carbon except at very high light intensities. Information was obtained on the composition of the excreted matter through the C^{14} technique. Several species were found to excrete measurable amounts of glycolic acid.

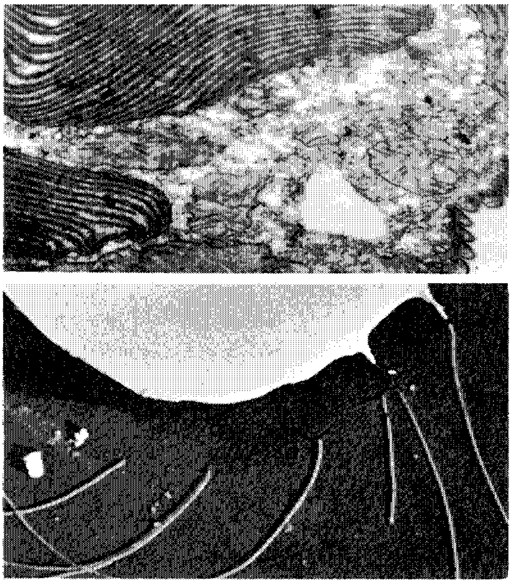
In contrast to the above work, other studies were concerned with the utilization of organic compounds by plankton algae. Phosphorus-deficient cultures were found to produce and release into the medium alkaline phosphatase capable of hydrolyzing certain organic phosphorus compounds. The released phosphate was thereby made available for assimilation.

In addition to the work concerning the excretion and utilization of organic matter by the phytoplankton, a nuclear weapons test provided the opportunity to measure the rate of excretion of several physiologically important elements (iodine, zinc, cobalt, iron, and manganese) by pteropods, pyrasomas, copepods, euphausids, and other zooplankton which were contaminated by fall-out. Of particular interest was the fact that zinc and iodine were excreted as soluble ions while iron and manganese appeared in the excreta in particulate form. These measurements provided confirmation for the postulate that the excretion and vertical migration of zooplankton may together provide a mechanism for an appreciable transport of elements across the thermocline. Related work was concerned with the chemical composition and bacterial content of the fecal pellets of marine copepods. It is hoped by this study to learn something of the chemical and biological changes undergone by phytoplankton which are consumed by herbivores but pass through their intestinal tract without being assimilated.

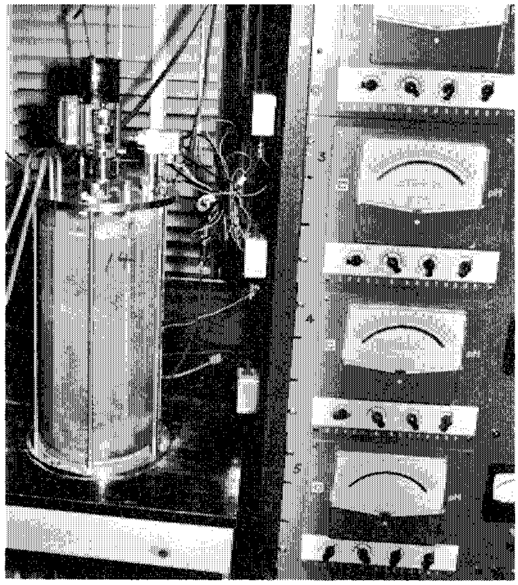
Finally, it has been demonstrated experimentally that bubbles rising through sea water may concentrate dissolved organic matter on their surfaces and carry it to the sea surface. Through vertical concentration and lateral compression into windrows by means of Langmuir circulation, these dissolved compounds may then be transformed into particles. By such a mechanism, dissolved organic matter may indirectly provide a source of food for filter feeding animals. Relating to these studies, the concentration of particulate matter in windrows was confirmed through use of an electronic ***in situ*** particle counter constructed in this laboratory.

Microbiology and Algal Physiology

Biochemical studies of the nitrifying bacterium ***Nitrosocystis oceanus*** have continued with the principal effort directed toward separating and purifying the enzymes responsible for the oxidation of ammonia to nitrite. Enrichment cultures from the Indian Ocean produced a new strain of bacteria capable of oxidizing ammonia to nitrite in thirteen to sixteen days in contrast to the period of thirty to sixty days required by the original culture. In addition, the first culture of a bacterium capable of oxidizing nitrite to nitrate was obtained from inshore Atlantic Ocean waters this year. Attempts are now being made to obtain both of these organisms in pure culture.



Nitrosocystis oceanus flagellum and bands are observed with the electron microscope.



Cultures are grown in Ph-stat fermenter built in Woods Hole.

The vitamin B_{12} specificity of marine diatoms was examined further extending both the number of species and the number of B_{12} analogues concerned. The morphology and mode of reproduction of diatoms and blue-green algae were also investigated, employing both light and electron microscopy. Partial success was obtained in attempts to control the production of gametes and auxospores at will in diatom cultures by manipulating environmental conditions.

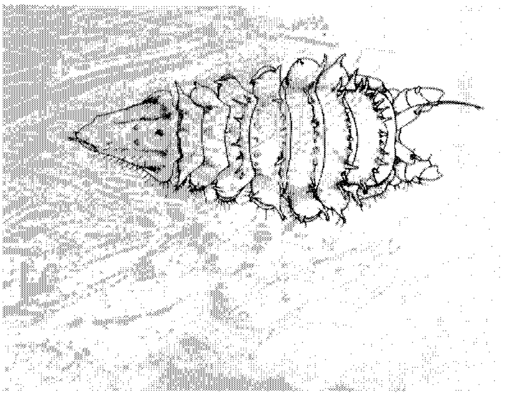
The decomposition of chlorophyll and the optical properties of the pigment and its decomposition products were studied using cultures of plankton algae. These findings were then related to the attenuation of light of different wave lengths in the ocean, absorption of light in the ultraviolet region being attributable to pigment degradation products while absorption in the red region is due to the pigments themselves in the living organisms.

Invertebrate Zoology

A series of plankton samples collected by the National Institute of Oceanography, Surrey, England, was made available to this Institution for systematic and distributional investigations of bathypelagic copepods. These samples were obtained from depths as great as 5000 meters from the eastern North Atlantic Ocean between 30° and 60° North Latitude, and they represent one of the most extensive collections of deep sea plankton in existence. Thirty new species and three new genera of copepods have already been described from these collections, and many unique and unexpected distributional characteristics have been recorded.

Metabolic and nutritional studies of the large Arctic copepod, ***Calanus hyperboreus,*** have been continued. Immature animals collected at different times of the year and reared in the laboratory under the same conditions produced different ratios of males and females, suggesting that some factor in the natural environment influences sexual differentiation in this copepod, with production of sufficient males for successful reproduction only when they are needed.

Preliminary investigations on the nutritive value of various species of phytoplankton to copepods indicate that certain species (e.g. the large diatom, ***Coscinodiscus***) are readily consumed and assimilated while others (e.g. the green alga, ***Dunaliella,*** and the common neritic diatom, ***Skeletonema***) are very poorly utilized.



Dorsal view of isopod *Ilyarachna sp.* taken from 500 meters on the continental slope south of New England.

Systematic analyses of the benthic invertebrates on a transect from Gay Head to Bermuda are now nearing completion. Principal efforts have centered on the three predominant groups of animals: pelecypods, isopods, and polychaetes. These three major faunal components show essentially similar distributional patterns, with no species having ubiquitous distribution and each restricted to a specific portion of the transect. There is strong evidence of a zoogeographical boundary in the region of the Gulf Stream.

More than half of the specimens by number in the bottom samples were polychaetes. In comparison with the five hundred known species of these worms resulting from one hundred years of collecting from all oceans at bathyal and abyssal depths, over two hundred species have been found in the twenty-six benthic samples taken between Gay Head and Bermuda. At least a quarter of these are new species.

Related studies of marine invertebrate larvae have revealed the presence of larval forms of many bottom dwelling animals far out into the open sea. Of particular interest is the distribution of certain sipunculid worm larvae which have been found from the Gulf Stream all the way across to the Azores, occurring more than a thousand miles from the nearest coast and several thousands of meters above the ocean floor. Efforts are being made to trace the distribution and origin of these widely dispersed larval populations.

Fishes

The year 1963 proved to be the most successful year to date for the Cooperative Game Fish Tagging Program, with seventy-six returns from 3400 fish tagged, more than the total of all accumulated returns from the Program up to this time. Continued growth of the purse-seine fishery for tuna and the long-line fishery for swordfish, both having received their impetus from this program, greatly increased the availability of these and other species for distributional records and examination of specimens. Ten exploratory fishing cruises were made along the continental shelf from Cape Hatteras to Nova Scotia and eastward to the Azores. Records and specimens now being analyzed will greatly expand our knowledge of the seasonal and areal distribution, migratory routes, growth, maturation, and reproduction of a wide variety of the larger pelagic fishes. Species included in these studies are the tunas, swordfish, marlin, sailfish, amberjack, bonito, and dolphin.

Research has also continued throughout the year on the skates and rays obtained by bottom trawling during 1962 and 1963 by U. S. Fish and Wildlife Service vessels operating along the south Atlantic coast, in the Gulf of Mexico, and southeast to the offing of Brazil. Extensive meso- and bathypelagic fish collections were also made by the ANTON BRUUN in the central Indian Ocean and by the CHAIN in the equatorial Atlantic off South America. These collections have been sorted and partly identified as a part of a long-range study of the systematics and zoogeography of these fishes.

department of chemistry and geology

John M. Hunt, Chairman

Manganese nodules and a variety of sessile organisms growing on the top of Muir Seamount.

Hydrocarbons in the Sea.

A study of the hydrocarbons in zooplankton from the Gulf of Maine has led to interesting results. Copepods of the genus ***Calanus*** contain several per cent of pristane, a highly buoyant hydrocarbon, which they derive from phytol in their diet. Other planktonic animals, except for predators which feed on ***Calanus,*** are much poorer in pristane, but may contain other species-specific compounds. These compounds probably find their way into the surrounding water mass at a concentration exceeding their detection limit. This may enable us to follow the movements of such a biochemically tagged water mass.

Apparatus for growing and harvesting marine algae under conditions excluding contamination with hydrocarbons has been put into operation. It will be used to study the species variability of hydrocarbon synthesis in marine algae and to define the structural and type differences between recent biosynthetic and fossil hydrocarbons in the sea.

An unusual compound containing a carbon phosphorus bond (aminoethylphosphonic acid) has been isolated from the local sea anemone ***Metridium dianthus.*** This amino acid analogue appears to be incorporated into the proteins of ***Metridium.*** The search for this and similar organophosphorus compounds will be extended to other marine organisms.

The aromatic hydrocarbons pyrene and fluoranthene have been isolated from manganese nodules, together with a large number of unidentified organic compounds. This finding extends the known range of natural occurrence of polynuclear aromatic hydrocarbons and suggests that compounds of this type are well preserved in strongly oxidized sediments deposited at high redox potentials.

The porphyrins of a Triassic oil shale have been reinvestigated by chromatography and mass spectrometry. The complexity of the pigment mixture is far greater than anyone had anticipated. Each of the forty-odd new pigments which were identified is the product of environmental modification of a very limited number of original pigments; each compound is indicative of the various organic processes which proceed in the subsurface sediments.

Chitin Synthesis

Enzymes which catalyze the formation of chitin have been prepared from the epidermis of molting crabs. The enzymes were used to synthesize an insoluble material from a C^{14}-labelled nucleotide sugar, which is the immediate precursor of chitin. Radioactivity was found to remain in the insoluble material even after extensive washing with acids and organic solvents. However, it could be removed by digestion with a chitinase to yield C^{14} acetylglucosamine. This indicated that the synthesized material is chitin. Various fragments of chitin molecules are now being investigated as enzyme stimulants in chitin synthesis.

Trace Elements in the Sea

Most trace elements are present in such low concentrations (micrograms per liter and less) that they must be concentrated from large volumes of water before being analyzed. An ion exchange resin column has been developed which retains these elements by forming stable dithizonates. A 1 x 10 cm column effectively concentrated zinc, copper, cobalt, nickel, cadmium, and lead from several thousand liters of both natural and artificial sea water. The concentrated elements are removed from the column with strong HCl and analyzed by polarography, and other techniques.

By using Millipore® filters in front of the resin-dithizone columns it is possible to determine the elements in particulate form as well as the dissolved species. The technique was successfully tested during a cruise of the CRAWFORD and will be used for trace element surveys in the North Atlantic this year.

Techniques still need to be developed to determine trace elements that are complexed with organic matter. This is the third and possibly the major form in which trace elements exist in the sea.

One approach to an understanding of trace element-organic complexes has been to synthesize the complexes and measure their uptake by sediment particles. Clays such as kaolinite and montmorillonite were found to take up a positively charged zinc-glycine complex as strongly as divalent zinc whereas a neutral complex was poorly retained. Other trace metal-amino acid complexes are being investigated.

Chlorinity of Sea Water

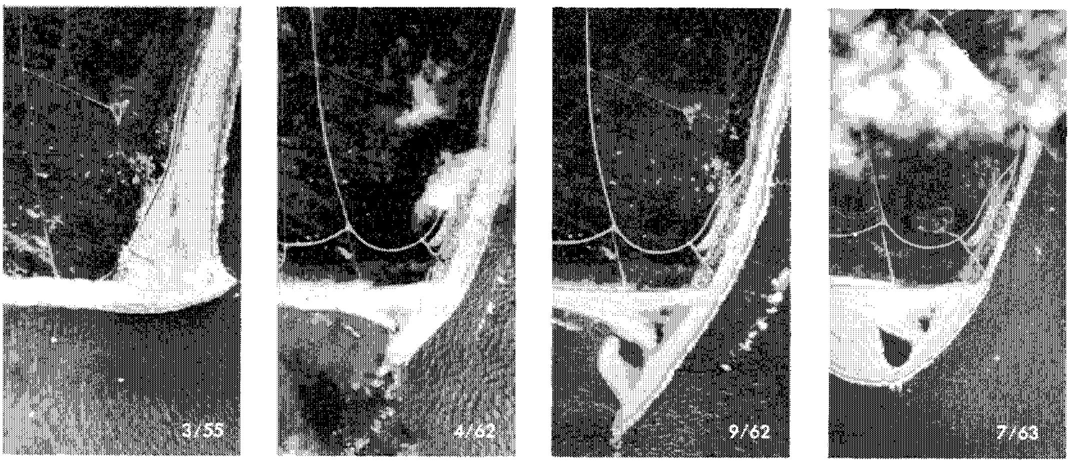
A coulometric device is being developed which will be capable of automatically analyzing for chloride ion, or total anions with a precision of one part in several thousand. Several refinements are needed to provide the required accuracy as well as precision. If successful, it will enable chlorinity to be measured in terms of fundamental electrical properties and time. It also may tell us more about the "constancy of relative proportions" of major ions in sea water.

Salt Bridges

The full capability of the salt bridge salinometer was developed in a sequence of highly successful measurements of the Pocasset River estuary. Salinity varied from 31 ‰ at the mouth to 0.5 ‰ at the top, and it changed widely with the tidal cycle. However, interstitial mud waters only a few millimeters below the bottom were more saline than the overlying waters and showed no change over a 24-hour period. Ground water seeping from below was easily recognized by dilution of interstitial mud waters.

Wave Structure

Equipment designed to measure the distribution of velocities within a breaking wave and the attenuation of surf height and length close to a beach was tested



Changes in the shore line at Cape Hatteras.

on Cape Cod and Saint Martin Island. Breaking waves damaged the instrument but it was possible to obtain some information on ripple formation beneath oscillatory waves. Ripples reformed completely in five minutes at a depth of four feet, in forty-five minutes at nine feet, and in three hours at twelve feet.

Shoreline Changes

Documentation of changes along the coastline of the eastern United States by aerial photography has been made periodically since 1954. Color movies and black and white verticals and obliques are available, with a more complete coverage for the storm-affected areas between Cape Cod and northern Florida.

Changes in the Cape Hatteras area are clearly documented in the accompanying photographs. Since 1945 the eastern beach has been almost static, while the southern beach, which was cut back about 1800 feet prior to 1958, has built up rapidly in the last two years to its former size.

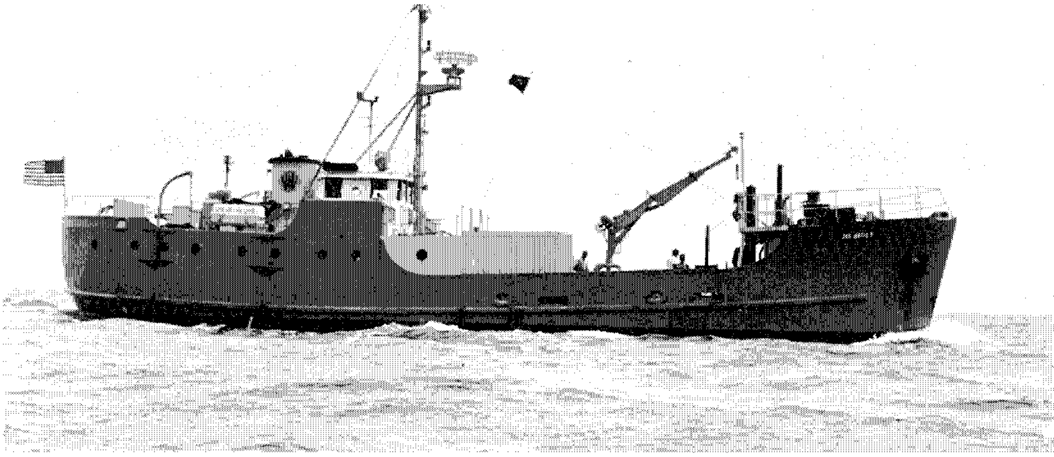
Fission Products

A vertical set of water samples from 0 to 3000 meters was taken in an area south of Greenland in February 1962 when fallout was exceptionally high due to the late 1961 bomb tests. It was assumed that Sr^{90} concentrations would show a marked decrease with depth since mixing is believed to be slow to depths below 300 meters. Surprisingly, the Sr^{90} concentrations were relatively constant down to 800 meters. At greater depths a colder, more saline layer of water was encountered which had about half the Sr^{90} of the shallow layers. These results indicate that in a uniform body of water mixing is fairly rapid through at least the first 800 meters in relation to the rate of fallout at the surface.

A one hundred per cent increase in the Sr^{90} of surface waters of the Chukchi Sea, which lies northeast of the Bering Straits, occurred between August 1959 and August 1961. Surface fallout was very low during this period, due to a moratorium on atmospheric testing. A possible explanation of this increase is that contaminated waters from high fallout areas in the Pacific took from two to three years to reach the Chukchi Sea.

Biogeochemical Studies

During the CHAIN's participation in the EQUALANT Program, an extensive series of biological, geological and chemical samples were collected, as well as data



GOSNOLD (99 ft.) has proved to be a most efficient sea-going laboratory.

for bathymetric studies of the Mid-Atlantic Ridge, around St. Paul's Rocks, the Guiana Shelf, and the Gulf of Paria. Scientists of the University of Parma in Italy, Tohoku University in Japan, the U. S. National Museum, and Oregon State University cooperated in the planning and subsequent analysis of the samples.

Geology of the Continental Shelf and Slope

The joint program with the U. S. Geological Survey for studying the geological history of the Atlantic continental shelf and slope is now staffed with twelve scientists, seven of whom are with the Survey. The GOSNOLD has been equipped for bottom sampling, echo sounding, and seismic profiling, and has been used on sixteen cruises. Some four hundred bottom samples have been collected from the area and are being analyzed together with earlier samples collected by the Bureau of Commercial Fisheries.

The area being studied extends from the East Coast to the limits of the abyssal plains, and from the Newfoundland Rise to the Puerto Rico Trench. Major topographic features seaward of the continental slope have been defined and their sources of sedimentation are being investigated. For example, Pleistocene glaciation has markedly influenced topography in the northern areas whereas carbonate sediments from Bermuda have influenced topography in the south.

Seven physiographic provinces have been defined on the continental shelf and slope. Continuous seismic profiles are showing the thickness of sedimentary units in areas such as the Gulf of Maine where the Mesozoic to Recent sediments average less than 200 meters in thickness.

Textural studies show that more than half of the samples from the northern part of the continental shelf contain a broad range of grain sizes including some gravel. Clay contents vary from five per cent to fifty per cent with the clay dominant in basins and the sand in shallower areas. However, ratios of different clay minerals are constant throughout the area. Topography appears to be the primary control over mineralogy although the influence of sediment source can be seen. Mineralogical studies show that the types of sediments being deposited today are completely different from those deposited in glacial times.

More than one thousand analyses for organic carbon and nitrogen and calcium carbonate have been made on the bottom samples. High concentrations of organic carbon lie in two belts, 50 and 150 km off shore, the highest values being in basins and the lowest on banks. It is suspected that the two belts may represent land-derived and marine-derived concentrations of organic matter.

department of geophysics

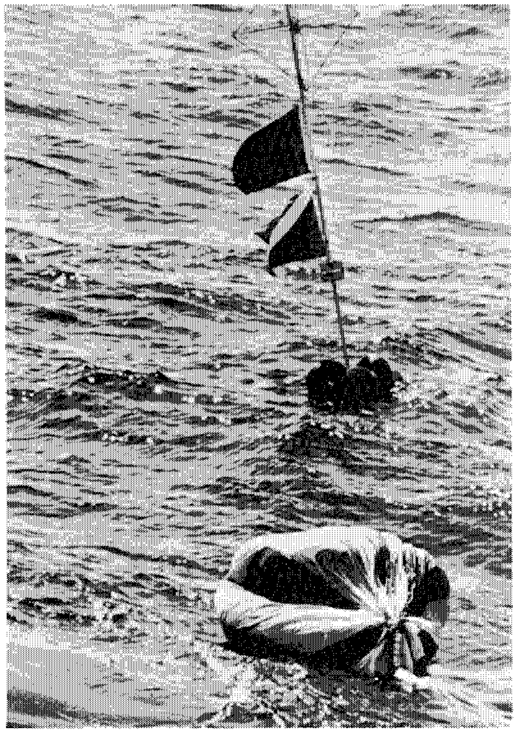
J. B. Hersey, Chairman

During the past year several members of the department have concerned themselves with automating the taking and reducing of repeated observations at sea, while others have been occupied for a major part of the year with the search for the lost submarine THRESHER. The ATLANTIS II was devoted to the search for THRESHER from the date of the disaster (April 10th) until June; the CHAIN made a cruise of two weeks during August to aid in the search as well. While many scientists from other departments contributed to the work required by the THRESHER emergency, the searching techniques that could be adapted in a short time were clearly those already employed in the work of the Geophysics Department. Hence, much of the time of several staff members was consumed in the preparation of instruments and in the carrying out of the search. Since August the fulltime attention of a few has been taken up with analyzing results.

For the remainder of the staff, individual and cooperative research has continued at sea, mainly on cruises of the ATLANTIS II and the CHAIN, and ashore at Woods Hole. As in previous years, the program of the department encompasses hydroacoustics, those parts of physical oceanography having to do with sound transmission in the sea, marine bioacoustics, and the geophysical problems of the lithosphere (crustal geophysics) and closely related problems of submarine geology.

Hydroacoustics

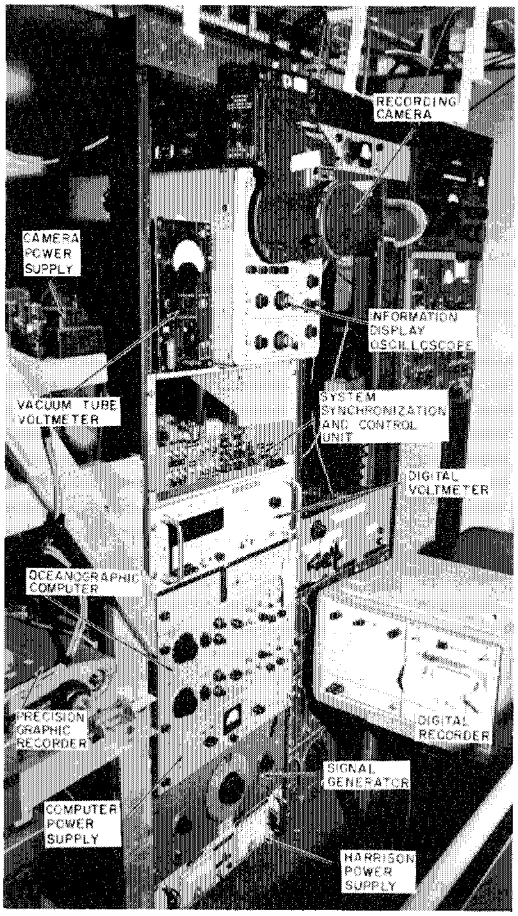
Considerable progress has been made on complex and detailed comparisons of



A Woods Hole navigation buoy at site of THRESHER's last dive.

sound levels, observed in transmission between a shallow source (explosive charges) and the hydrophones distributed through the top 600 feet of the water column (on the thermistor chain), and a ray-theory model of transmission based on the temperature structure observed simultaneously with the thermistor chain. A very large sample of acoustic data has been treated by digital data-handling methods and computations of sonic transmission using the model have been made. The results of two analyses are being compared by automatic programs which are also being plotted automatically for visual study. The preliminary indications are that the ray model can be used to account for gross detail except in those parts of the sound field where scattering and diffraction appear to be the dominant modes of transmission.

A similarly detailed and lengthy series of measurements of bottom loss (inverse of reflectivity) has been reduced by means of digital computers. Measurements were made by feeding the echo from the echo



Sea-going instruments used to measure acoustic energy bottom loss.

sounder through analog computing equipment to an oscilloscope from which the resulting wave form was photographed according to an automatic program of selection. The results of the acoustical measurements have been compared with physical properties of the sediments forming the bottom where the acoustic measurements were made. In accord with earlier results, a marked positive correlation between bottom loss and porosity and grain size was found. The principal achievement has been the large-scale demonstration of this relationship through the development of a technique for surveying the ocean floor for bottom loss and related geological characteristics using an ordinary echo sounder and modest accessory equipment. This investigation is confined to reflections at normal incidence and to the 12-kc frequency of the echo sounder used, thus limiting the information that can be interpreted. But the methods developed during this investigation for analyzing single received pulses of sound energy are expected to prove useful in programs now underway for studying reflections from the bottom at oblique angles. These investigations merge with measurements of acoustic impedance, velocity, and velocity gradient, which are also underway.

All of these programs depend upon the successful development of radio-acoustic buoys. This development work was considerably advanced in 1963 with the design and construction of buoys that would transmit continuously for periods up to a week in length. Also, in connection with improving navigation for the search for THRESHER, an excellent start was made at developing a tethered buoy whose receiving hydrophone can be placed at any desired distance above the bottom in deep water.

Physical properties of the sea floor have been observed by means of sound backscattered to a receiver near the source. During several previous years these observations, using explosives and single hydrophones, have been made in many locations in the North Atlantic Ocean. The reduction of the data and their comparison with theoretical models of scattering from a rough surface (or a thin layer) has progressed well this year, largely by designing digital computing programs to this end.

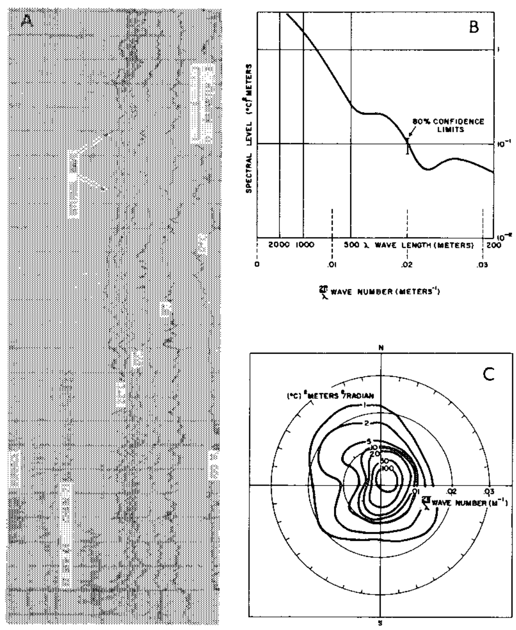
As part of continuing research, an area near Bermuda of about a thousand square miles was sounded in considerable detail both with echo sounders and the Continuous Seismic Profiler. This provided data for a theoretical model to compare with oblique bottom reflections from the same area of the bottom during detailed horizontal transmissions of sound. This is an important problem of sound transmission which has received but scant attention at sea.

Physical Oceanography

The year has been devoted mostly to analysis of data taken previously, both in measurements of sound velocity in sea water and in observations of internal waves by means of the thermistor chain or similar instruments. Data about the thermal fronts discovered southwest of Bermuda have been analyzed. These fronts have proved to be boundary currents in approximate geostrophic balance, but their full extent and persistence is not yet known. A three-week cruise to the area has been scheduled for early 1964 to obtain further information about these fronts. This work is being done in cooperation with the Physical Oceanography Department. The internal-wave program, also an interdepartmental effort, has resulted in a successful analysis for direction and period of the two-dimensional spectrum of an internal wave field, as well as several one-dimensional spectrum analyses (period only) based on the extensive collection of thermistor chain recordings. These analyses clearly demonstrate the concentration of internal-wave energy at the long-period end of the spectrum and the absence of any marked concentrations of energy (spectral lines) in short-period waves.

Marine Bioacoustics

Our program in marine bioacoustics is twofold: We are studying both the sound production and the sound scattering properties of marine animals. A principal interest has been the sounds produced by marine mammals (cetaceans and pinnipeds), with less active interest in other classes of sound producers such as fishes and crustaceans. Sounds of captive pinnipeds (seals) recorded at the New York Zoological Society show that they produce a variety of clicking sounds faintly reminiscent of porpoise clicks. These may be too faint for echo-location, but because they were observed in captivity and in a limited environment this point can scarcely be regarded as settled. A series of combined listening and whale-watching observations extending over several years has led to the conclusion that certain very strong, low-frequency pulses (i.e. 20 cps), observed widely in the ocean, are produced by the ubiquitous finback whale (***Balaenoptera physalus***). High-pitched clicks previously associated with sperm whales (***Physeter***) have recently been shown to exhibit highly individual characteristics which may serve to identify individual animals. Further, each individual click is emitted as a pulse of sound somewhat analogous to the technique frequently employed in sonar work for recognizing an echo in noise. A dissection of the



Internal waves at about 34°N, 12°W.

A. Thermistor-chain record of temperature structure.
B. Two-dimensional spatial spectrum of mean square temperature fluctuations at 90 meters.
C. The spatial spectrum averaged in all directions.

laryngeal region of a porpoise, ***Stenella styx,*** has contributed to a better understanding of the sound-producing mechanisms in these animals.

A deep scattering layer between the continental shelf and the Gulf Stream off our coast differs from the usual deep-sea layers, which are generally continuous, by being characteristically patchy. The layer exhibits the resonant response found in the scattering spectrum of many deep scattering layers and migrates from a mid-day depth of about 180 fathoms to the surface at night. No technique for positive identification has succeeded in isolating the animal scatterer, but suspicion centers on the gempylid ***Nealotus tripes*** which has been observed in great numbers at the surface at night shortly after the evening ascent of this layer.

In addition to acoustical research, extensive collections of fishes were made during the EQUALANT cruise of the CHAIN for systematic and zoogeographic purposes. The determining of faunal boundaries in the Atlantic Ocean from such collections and the comparison of faunal composition with mid-water sound-scattering are central concerns.

A program of shark catching carried out for a decade over the deep ocean from several ships has allowed some progress in determining the distribution of these interesting large animals in the western North Atlantic.

The distribution of benthic fishes in deep water, as revealed by bottom photographs, is being studied. A comparison of benthic fishes in the Red Sea and the Gulf of Aden based on photographs taken during ATLANTIS cruise 242 to the Indian Ocean has been completed, and the thousands of bottom photographs taken on the continental rise south of Nova Scotia during the search for the THRESHER are now receiving similar attention.

Crustal Geophysics and Submarine Geology

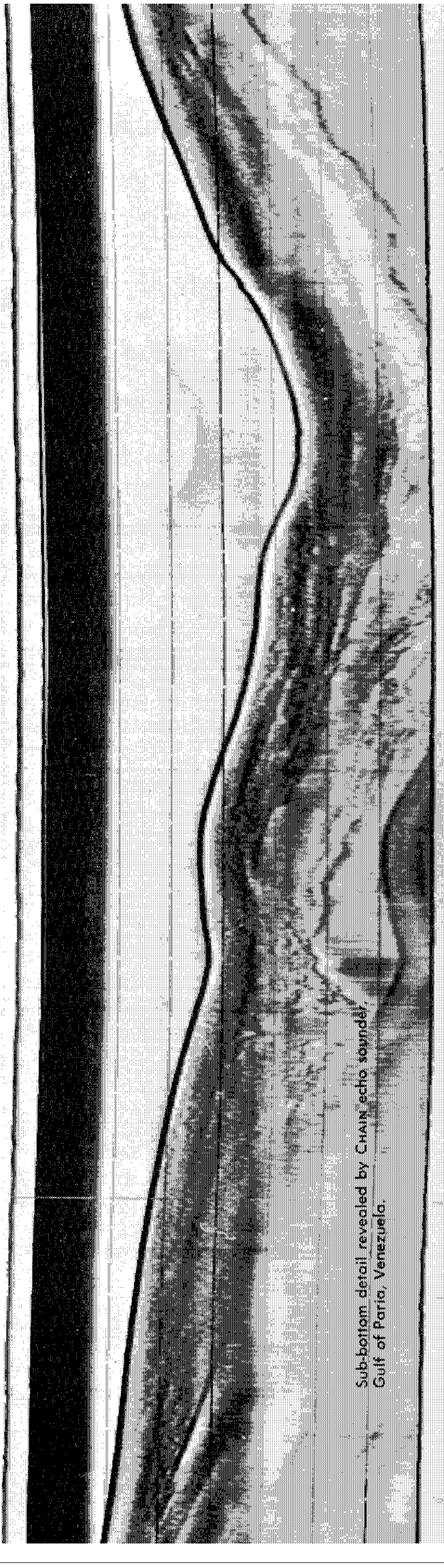
The search for the THRESHER was, for this department, largely an exercise in the methods of submarine geology which have been under development here for the past seven or eight years. Acoustically-controlled bottom cameras were used to make continuous coverage of the bottom over long lines of search. From these data photomosaics have been made revealing details of the bottom in strips several thousand feet long and fifteen to thirty feet wide. A remote echo-ranging apparatus was used to discover the presence of objects protruding above the bottom in the hope of discovering the hull or parts thereof. Debris from the submarine was first located by photographs taken from ATLANTIS II. The echo-ranging apparatus showed great promise as a means of searching the ocean floor either for artifacts or for geologically significant targets such as boulders or outcrops. The camera was accurately located relative to the towing ship by means of the camera pinger and an array of receivers at the ship.

The Precision Graphic Recorder (PGR) was a critically important instrument. Its special short-pulse controls provided excellent records throughout, whether the mission was echo sounding, echo ranging, or positioning the camera near the bottom

Seismic refraction profiles were made between the ATLANTIS II and the CHAIN on the Outer Ridge north of the Puerto Rico Trench; this series was accompanied by seismic-reflection profiles and gravity measurements on the CHAIN over the Outer Ridge and later over the Barracuda Scarp, west of Guadaloupe Island in the lesser Antilles. Successful dredgings, yielding basalt, were made on the Barracuda Scarp, and heat-flow measurements over this whole region were extended. These latter departed little from world averages. In a later cruise of the CHAIN, bathymetric, seismic reflection, gravity, heat flow, and combined dredging and photographic surveys were made over a large group of abyssal hills located about two hundred miles southeast of Bermuda. Special interest attaches to these hills because they appear to be an exposed part of the rough surface of high velocity rock (about 5.2 km/sec) which elsewhere in the North American Basin is largely buried beneath thick layers of sediment. The expedition was successful in showing that the abyssal hills are probably a series of north-south trending ridges and that only some of the valleys between are thinly covered with sediments. Red clay was recovered in several dredge hauls while from one a manganese nodule with a basaltic core was recovered.

The sparker sound-source was redesigned to increase the energy input from 25,000 to 100,000 joules and to improve reliability and ease of maintenance. It was used in making long profiles between Woods Hole and Bermuda, as well as for the expedition to the abyssal hills. Concurrent with the improvement of the sparker sound-source, improvements have also been made in reception equipment and analysis techniques.

Over the past several years, a concerted effort has been made to chart and tabulate bathymetric data from all cruises supported by the Institution in a standard format. As a result, all bathymetric data recorded since 1958 have been processed, while considerable progress has been made in processing the older data. Microfilming equipment has been put to efficient use during the year in copying the entire file of thermistor-chain records and a large portion of the echo-sounding and seismic profiling data. Other original data such as bottom photographs, which are of general interest, have continued to be processed and made available as required.



Sub-bottom detail revealed by CHAIN echo sounder, Gulf of Paria, Venezuela.

Analyses of various rock collections from dredgings on seamounts, on the north wall of the Puerto Rico Trench, from the Mid-Atlantic Ridge, and from the Barracuda Scarp have been continued during the year. Recent collections from the north wall of the Trench contain many samples of both sedimentary rock and a basalt having a velocity slightly above 5.0 km/sec. The chemical and mineralogical examination of the basalts and serpentinites is incomplete, but basalts both from the north wall and Barracuda Scarp are similar to oceanic basalts previously described. It seems likely that the north wall basalts were implaced beneath the deep ocean.

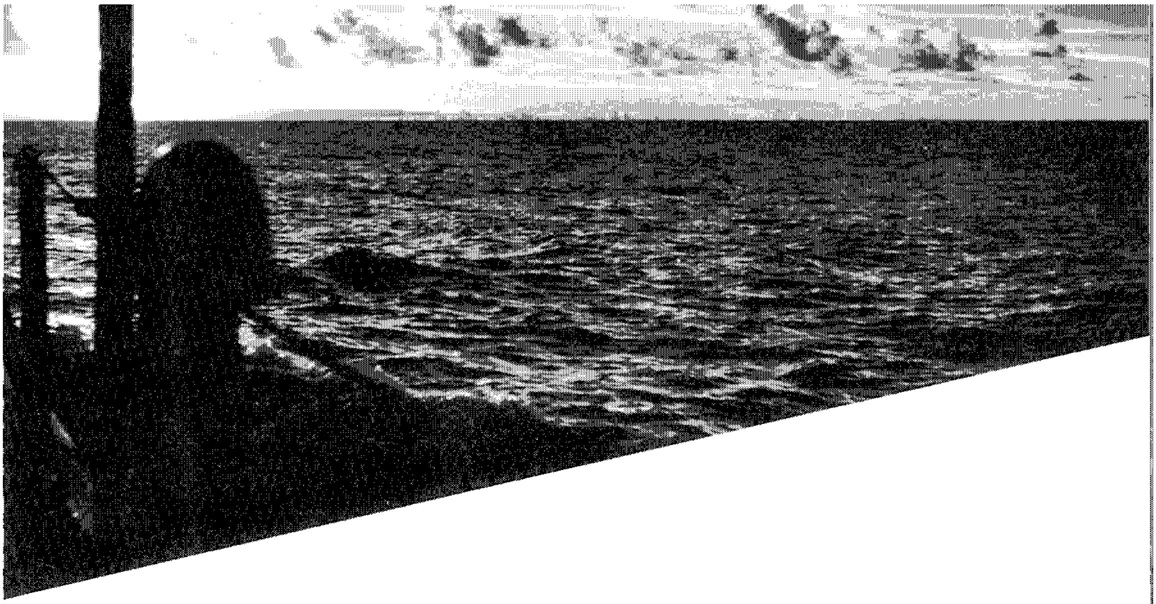
Limestone recovered from the north wall has been found to be Cenomanian (basal upper Cretaceous). It is thought that the temperature of water in the deep ocean during Cenomanian times was warmer than at present, allowing the deposition and preservation of calcium carbonate at greater depths than is presently possible.

Statistical analysis of North Atlantic topography taken from long oceanic crossings shows a distribution of apparent slopes, slope-lengths, and curvatures. There is a positive correlation between average slopes and average curvatures, as expected, but there is a pronounced gap in the distribution of average curvatures, with no values at all between about 0.8° and 1.0° per mile. Taking into consideration correlations of slope and slope length above and below this gap, it has been suggested that the gap marks the dividing zone between low slopes and curvatures where sediments completely blanket former irregularities of topography, and more highly sloping regions where this is not the case.

Gravity Data Reduction at Sea

Elaborate preparations, including an extensive and successful test at sea, have been made for providing the CHAIN with an automatic digital data logging and reduction system to be used during the International Indian Ocean Expedition. The system is built around an IBM 1620 general-purpose digital computer. It is augmented by an IBM 1623, which provides additional core storage, and by magnetic-disc, random-access memory units for storing data. Special analog-to-digital converters receive gravity, magnetic, navigational, and bathymetric data automatically and place these data in storage. Routine data reduction programs calculate gravity anomalies, depth profiles and navigational plots on board the ship. Logging typewriters in the laboratories and on the bridge permit other verbal and numerical observations to be recorded in disc storage without mutual interference with the routine data-collection program. From the past two years' experience with on-line data reduction at sea there is reasonable expectation that this method of data collection will be a considerable improvement in quality over the hand-written logs and analog recordings of the past.

In February, a gravity survey of Haiti was made to complement one previously made of the Dominican Republic; these surveys were being extended seaward late in the year but a rupture in the fire main on the CHAIN flooded the auxiliary generators and forced the postponement of the work. Gravity measurements over the Outer Ridge north of Puerto Rico and over other features in the North Atlantic were reported last year on the basis of on-line digital data reduction performed during the cruise. The final reduction of these data has now been completed. Had a survey of such scope been undertaken without digital computing and storage, the first preliminary reduction of data would not yet have been completed even if the full time of the group interested in gravity had been devoted solely to the computations.



department of physical oceanography

Frederick C. Fuglister, Chairman

Members of this department participated in two international cooperative ventures during 1963: EQUALANT I, an investigation of the Atlantic equatorial current systems, and the International Indian Ocean Expedition.

EQUALANT I

The principal purpose of our participation in this venture was to obtain further information on the Atlantic Equatorial Undercurrent which we had investigated in 1961. The CRAWFORD and the CHAIN took part in this work from mid-January to the end of April.

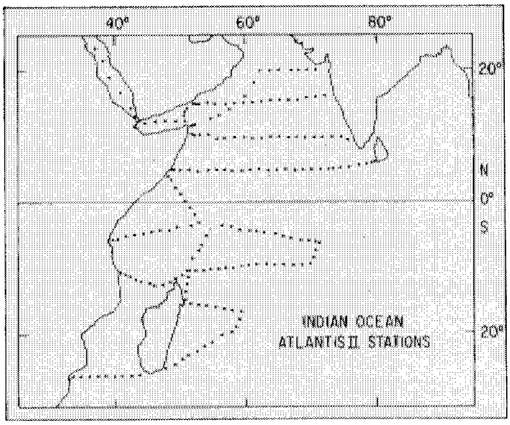
The shallow, eastward flowing undercurrent beneath the westerly moving surface water at the equator was thoroughly investigated between 25° and 40° West Longitude. Buoys, towed by parachute drogues in the Undercurrent, showed subsurface flow to the east of about a knot and a half. In addition to the one hundred and seventy hydrographic stations made to determine the water mass distribution over this large area, the ***in situ*** salinometer was successfully employed to delineate the sharp salinity-maximum core of the Undercurrent. The principal source of this water appears to be in the South Atlantic.

Moored current meter stations were set out from the CHAIN in groups of five, with each buoy supporting four current meters. After a week of continuous recording, the stations were moved to another location. One series of stations, recording for one minute in each twenty-minute interval, was left in place for two months. Some fifty usable records were obtained and it seems safe to assume that a large volume of good information about the Undercurrent will be extracted from them when the data are analyzed.

The Indian Ocean

It is too soon to speak of the scientific results of the first long voyage of the ATLANTIS II. On December 20 she returned from a 30,000-mile cruise that, starting on July 5, took her to the Mediterranean and the Red Sea, and thence criss-crossing the Arabian Sea and the western Indian

Ocean south to Cape Town, ending with a long, virtually straight run from the tip of South Africa to Woods Hole. The principal purpose of this cruise was to carry out a survey of the Arabian Sea during the height of the Southwest Monsoon; this was done in conjunction with the Royal



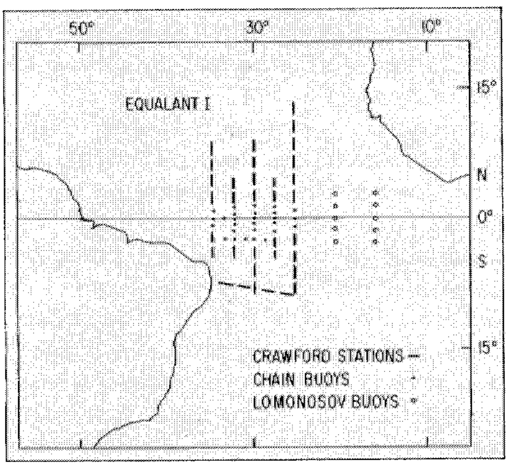
Research Vessel DISCOVERY which was working at the same time off the coast of Oman. Of special interest to many oceanographers will be the numerous observations obtained in the Somali Current. The task of organizing, analyzing, and publishing the material from this expedition will require a major effort in this department.

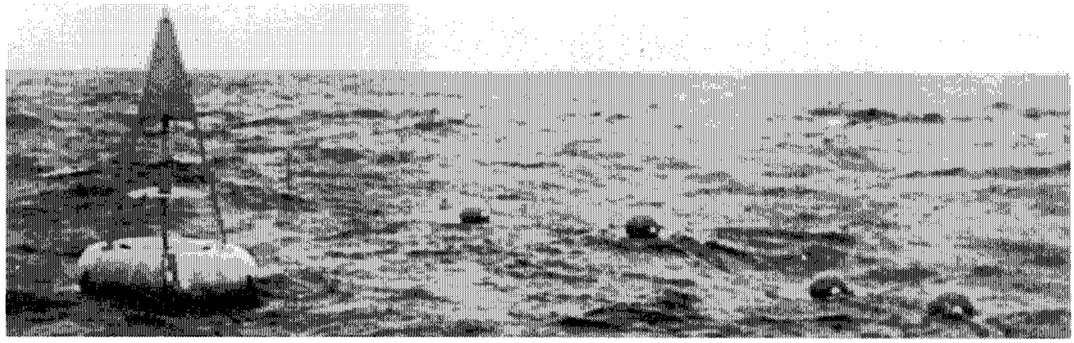
Water Masses and Circulation

Five studies of relatively large-scale water masses and their movements were undertaken during the year: the change in the slope water conditions in the year 1959, the gradual warming of the deep water in the Caribbean, the sequence of changes in the Romanche Trench area between the deep waters of the Western and Eastern Basins of the Atlantic, the extent of spreading in the Atlantic Ocean of Mediterranean Water, and the downstream increase in volume transport of the Florida Current. All of these studies were based primarily on the distributions of temperature and salinity. The volumes of water considered are very large but, except in the case of the Florida Current, the movements are slow; in general no current measurements, direct or indirect, were involved. An investigation of thermal fronts observed to the southwest of Bermuda indicates that there may be boundaries between different water masses in the surface layer of the ocean. Distinct currents associated with them as observed by the geomagnetic electrokinetograph flowed generally toward the east.

Direct Current Measurements

The optimism generated toward direct current measurement by the introduction of Swallow's neutrally buoyant floats and Richardson's moored current meters has been tempered through practical experience. New, significant information has been obtained with these instruments but the net results have fallen far short of early hopes. The neutrally buoyant float method is slow and spotty, requiring at the same time considerable skill on the part of the investigator and many hours of ship time. The moored current meters have yielded only a very small fraction of the information expected, largely because of instrument loss but also because of inadequate readout systems and confusion between motion of the sea and





motion of the instrument. Furthermore, the fluctuating deep motions indicated by both instruments are much greater than anticipated, making it more difficult to interpret current measurements. Very considerable effort has been and will continue to be applied to the analysis and improvement of these systems, both in this department and in the department of Applied Oceanography, but measurements with these instruments continue at a modified pace for the present.

The current meter work done on EQUALANT I was described above; on the Indian Ocean cruise a Braincon current meter, lowered from the ship and recording on deck, was used on the edge of the north flowing Somali Current and at several locations between northeastern Madagascar and the Seychelles Islands. Neutrally buoyant floats were used primarily on the summer student cruises from the ATLANTIS in the Gulf Stream and on a CRAWFORD cruise to the southwestern Sargasso Sea last fall.

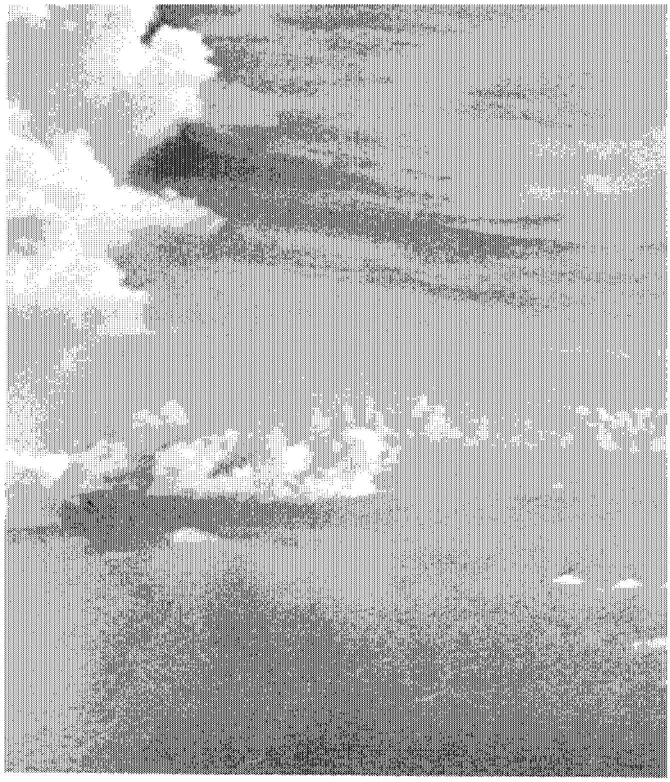
Direct current measurements using drogues were made during February and March in the Tongue of the Ocean and in the Northeast Providence Channel. The measurements suggested that the prevailing northeasterly and easterly winds caused a flow into the Channel in the upper 200 meters of water, producing speeds over 50 cm/sec. No steady deep circulation was found; a somewhat turbulent motion was observed down to 1500 meters with speeds generally less than 40 cm/sec.

Records from two current meters on a moored buoy 250 miles south of Bermuda were recovered in January. One instrument at 50 meters functioned 82 days, and the other, at 100 meters, for 108 days. The net movement over these periods was toward the north although at the end the 100-meter record showed a southerly flow. Rotational movement was apparent in the daily patterns; a clockwise motion occurred in general between midnight and noon, after which the movement was northerly.

A program for using drogued telemetering buoys to observe the circulation of the western and northern Sargasso Sea is in progress. A dual frequency Consolan receiver and switching complex has been designed, constructed and successfully tested on the existing buoys under field conditions. Signals from the Consolan stations at Miami and Nantucket are received by the buoys and retransmitted to receivers on shore, thus providing the location of the buoy.

Circulation on the Continental Shelf

Moored current meters, drogued telemetering buoys, drift bottles for surface flow and sea bed drifters for bottom flow were all used on this program. Mutually consistent results were obtained with these various tools in work done off Cape Kennedy (formerly Cape Canaveral): during March and April there was a predominantly northerly non-tidal drift of approximately 12 cm/sec. and during August a southerly drift of approximately 4-5 cm/sec. The drift bottle program during the past three years off the southern Atlantic states shows a northerly, non-tidal drift from March through May, a transition during June, a southerly drift from July through November, and an apparent offshore component (no recoveries) during the rest of the year. The sea bed drifters yielded a higher percentage of returns than anticipated with good returns during the winter months. The year-round onshore drift along the bottom tends to reinforce the concept of the estuarine character of the continental shelf circulation.



Average Surface Temperatures

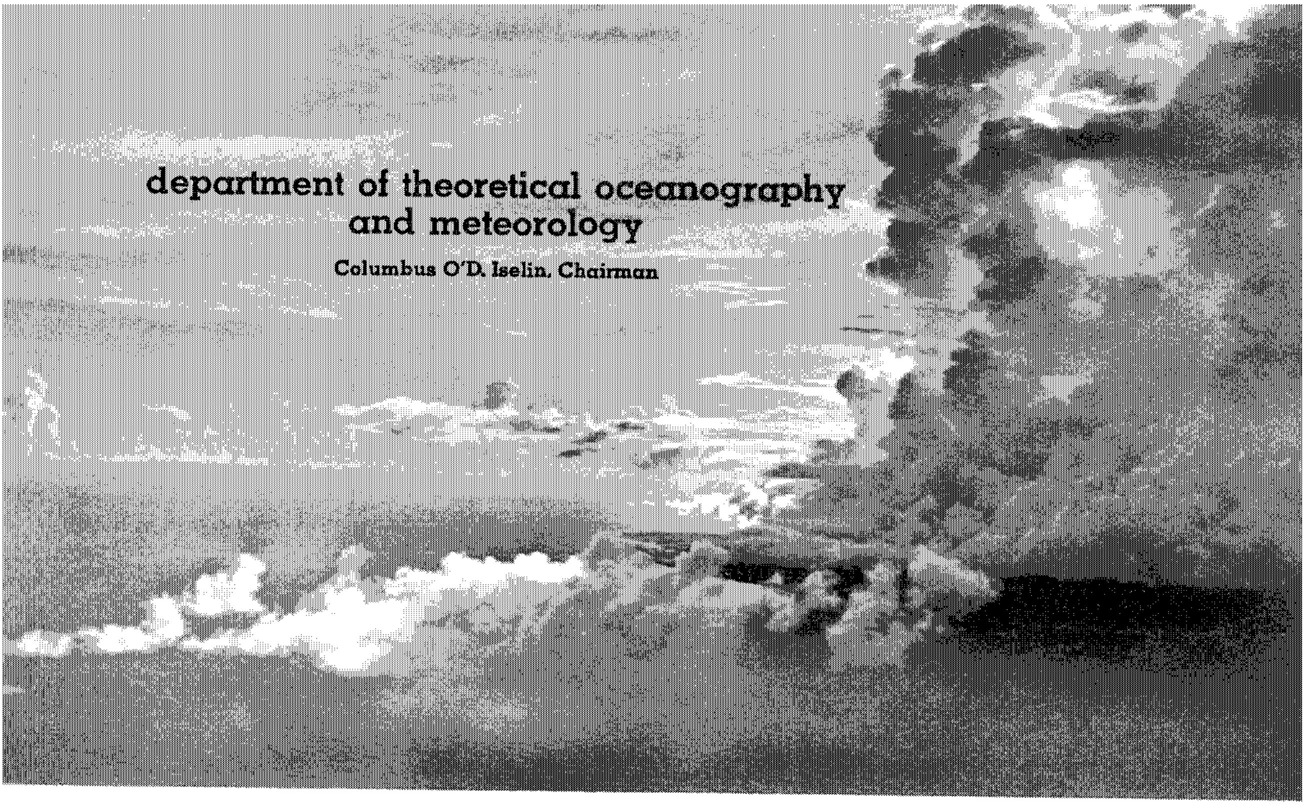
A motion picture strip showing the changing sea surface temperatures throughout the year along the east coast and in the western Sargasso Sea was constructed. It is based on the monthly average temperatures of each one-degree quadrangle in the area. A seasonal curve was drawn for each unit of area and monthly and half-monthly charts were constructed from the curves. These charts were in turn used as a basis for the drawing of 384 charts needed to complete the animation.

Internal Waves

Three series of measurements were investigated to determine the spatial spectra of internal waves and their directional characteristics. These measurements were obtained to the east of Madeira in 1961, at the equator during EQUALANT I, and north of Bermuda in 1963. A temperature sensing element was towed on various courses at a depth of about 80 meters in the thermocline. The records were digitized and the spatial spectra of the internal waves computed. Spectra have been obtained for wave lengths from 100 to 10,000 meters; all show that the greatest internal wave amplitudes occur at the longest wave lengths. In one case, examined for directionality, the internal waves with the smaller wave lengths appeared to be propagating down wind.

Salinometers

The shipboard salinometers are being redesigned and rebuilt. In order to cut down on maintenance time and to increase the stability, the bridges are being converted to transformer bridges and everything is being removed from the oil bath except the cells, some switches and variable resistors. The electronics section will be transistorized. The ***in situ*** salinometer is being changed from a salinity-temperature-depth instrument to a conductivity-temperature-depth instrument. An investigation of the effect of pressure on the specific conductance of sea water was completed. The accuracy of the results is estimated to be equivalent to better than ±0.01‰ salinity units.



department of theoretical oceanography and meteorology

Columbus O'D. Iselin, Chairman

Air-Sea Interaction

Several approaches to air-sea interaction studies have been refined or developed during the past year. While in one sense the work of the members of the department has always been concerned with air-sea interaction phenomena, recently several of the staff have begun to look into the exchange of energy and water vapor across the sea surface in increasing detail. Field measurements rather than theory are beginning to be stressed. Actually, the year was one of stock-taking and evaluation for some who had collected extensive data in the field during 1961-1962.

Facilities

The wave tower in Buzzards Bay has produced some very high quality data and shows quite clearly that at least for small waves, the highest part of an individual wave is traveling faster than the lower two sides so that the crest of the wave as a whole is slightly cusp-shaped.

An inexpensive stable moored platform for use in depths of 200 meters or less has also been designed, tested and instrumented. It is planned to use it first in trade wind latitudes.

A four-engined aircraft was modified as a flying meteorological laboratory during the first half of the year and fitted out with the following equipment: a thermistor psychrograph, solar radiometers, cloud camera, dropsondes, Doppler radar, search and weather radar, turbulence and turbulent flux measurement recorders. Extended flights have been made both in the Indian Ocean and in the Caribbean area. In addition, new equipment for air-sea interaction studies aboard the Institution's ships have been greatly improved.

The laboratory serving the new rotating basin has been extremely busy and its capabilities have been increased considerably.

Indian Ocean

A six-week trip to the Indian Ocean area was made in June and July to study the southwest monsoon weather. Flights were made out of Bombay to collect data over the Arabian Sea for the International Meteorological Center at Colaba Observatory. These observations included temperatures, humidities, winds, clouds, and radiation. In addition, measurements of the turbulent fluctuations of the wind, temperature and water vapor were secured in such a way that the fluxes of these factors and the momentum through the atmosphere could be computed at Woods Hole. Reduction of the data and preparations for a second flight are virtually completed.

Open Ocean

Long suspected, it has now been established from weather ship data that there is a definite diurnal variation in the amount of precipitation over the open sea with the greatest quantities falling during the night. Now, with synoptic data accumulated over the past fifteen years, a systematic examination of the vertical heat flux and evaporation is in progress.

Space Charge and Potential Gradient

From data gathered on field trips in 1961-1962, there is enough evidence to support the hypothesis that a flux of positive charge is being carried from sea to air by drops mostly from bursting bubbles at the sea surface. These particles arise from the sea due to the action of the wind and waves. When molten lava flows into the sea, the charge separation is extremely high and cannot be explained by existing hypotheses. The effect of dissolved organic material in the sea and particle and charge production at the sea surface requires much further study.

Cloud Physics and Related Phenomena

A visit to Barbados had the dual purpose of examining the interactions of the trade winds with the island and for relating cloud patterns observed from an aircraft to TIROS photographs. Indeed, photography is a major tool for collecting both phenomena and data. Hundreds of feet of ciné color films of cloud formations and hundreds of black and white photographs supplement other types of observations.

In addition, the development of tropical marine showers was tracked by radar. Small showers were selected and the rate of change of radar reflectivity within them was measured. An increase in reflectivity is interpreted in terms of the growth of small rain drops. The magnitude is consistent with estimates of the rate of coalescence of drops due to gravity. Thus, in the clouds examined, the role of drop electrification in enhancing the growth process is probably small. Measurements were also made of the manner in which the peak reflectivity in shower clouds was related to the maximum height attained by their summits. A strong correlation was obtained showing a rapid increase in reflectivity in the height range of 12,000 to 17,000 feet and a saturation thereafter. Thus, the reflectivity (and hence the rain intensity) from a cloud 50,000 feet high is not substantially larger than that from a cloud only one-third the size.

Oceanographic Forecasting

With the publication of Folio 2 of the Serial Atlas of the Marine Environment, the first step was completed in providing up-to-date statistical information for forecasting the mean near surface thermal structure in the North Atlantic and in the Mediterranean.

Work has begun on the more difficult task of preparing monthly charts of the depth of the wind-stirred surface layer (layer depth). Some trial forecasts at sea of layer depth have been carried out and a beginning has been made to assess the weaknesses of existing forecasting techniques, both by computer techniques and with hand-contoured semi-synoptic data.

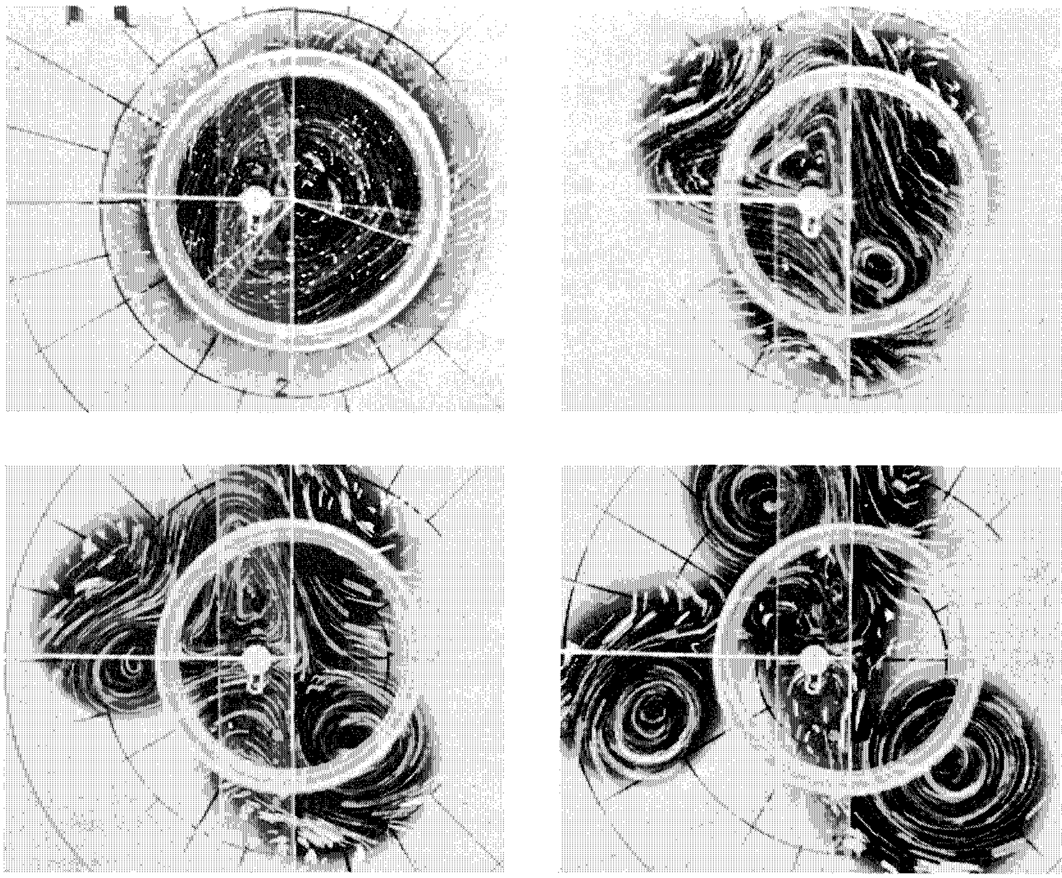
Experiments with a Rotating Basin

Experiments using a model basin are used to illustrate a number of important processes operating in the oceans and atmosphere. In addition, they pose certain interesting theoretical problems. Thus, the characteristics of certain baroclinic vortices were determined. The vortices were generated in a large rotating cylinder by introducing a column of heavy fluid in the central region of an otherwise uniform fluid.

Theoretical and Laboratory Models of Dynamic Processes

A simple experiment with carbonated water in a well-cleaned liter beaker on a rotating turntable provided a good analogy for the mechanism for tornadoes and waterspouts. The model is driven by convection and takes into account the affect of the ground below.

A kinematic model for the motion of buoyant "thermals" gives good agreement with earlier observations. The overall motion can be predicted from the nature of the exterior flow alone. Some progress has also been made toward a detailed description of the interior velocity and density distributions.



The break-up of a cyclonic vortex into three vortices in the model basin.

Cruises 1963

ATLANTIS

Days at Sea–95 | Total Miles Sailed–9,401.9

CRUISE	DATES	AREA OF OPERATION	DAYS	SCIENTIST
290	4–8 January	To Riverside Yacht Yd., Jacksonville	5	- - - - -
291	8–12 June	Florida to Woods Hole	5	- - - - -
292	13–29 June 15–28	Student Cruise – Cont. Shelf to Sargasso Sea	17	R. Munns
293	30 June–3 July	Edge of Shelf – South of Nantucket	4	F. Hess
294	6–19 July	Student Cruise – Cont. Shelf to Sargasso Sea	14	D. Fahlquist
295	20 July–1 Aug.	Student Cruise – Cont. Shelf to Sargasso Sea	13	J. Barrett
296	2–14 Aug.	Student Cruise – Cont. Shelf to Sargasso Sea	13	J. Reitzel
297	16 Aug.–2 Sept.	Student Cruise – Cont. Shelf to Sargasso Sea	18	J. Barrett
298	4–8 Sept.	Slope Waters	5	R. Scheltema
299	19 Sept.	To Munro's Shipyard	1	- - - - -

ATLANTIS II

Days at Sea–285 | Total Miles Sailed–41,882

CRUISE	DATES	AREA OF OPERATION	DAYS	SCIENTIST
	29–31 January	Baltimore to Woods Hole	3	- - - - -
	7, 12, 15, 18 Feb.	Trial runs local–Woods Hole	4	- - - - -
1	21 Feb.–5 March	Bermuda	13	J. Reitzel
	11–29 March	Bermuda	19	J. Reitzel
2	2–10 April	*Thresher*	9	N. Corwin
3	11–27 April	*Thresher*	17	J. B. Hersey
4	30 April	To Rhode Island for Fuel	1	- - - - -
5	2–15 May	*Thresher*	14	E. Hays
6	21–27 May	*Thresher*	8	S. Knott
	28 May–17 June	*Thresher*	20	D. Fahlquist
7	19–27 June	Shipyard, Baltimore	9	- - - - -
8	5 July–19 Dec.	Indian Ocean Expedition	168	A. Miller

CHAIN

Days at Sea–234 | Total Miles Sailed–34,647

CRUISE	DATES	AREA OF OPERATION	DAYS	SCIENTIST
35	23 Jan.–18 May	Equalant I, South America	116	G. Day and W. Richardson
36	4 June–10 July	Puerto Rican Trench	37	E. Bunce
37	17–26 July	Edge of Shelf – South of Nantucket	10	C. Yentsch
38	4–17 August	*Thresher*	14	J. B. Hersey
39	23 Aug.–23 Sept.	Continental Shelf	32	D. Caulfield and E. Bunce
40	25 Sept.–25 Nov.	Munro's Shipyard		- - - - -
41	1–25 Dec.	Jamaica	25	C. Bowin

Cruises 1963

CRAWFORD — Days at Sea–264 — Total Miles Sailed–31,902

CRUISE	DATES	AREA OF OPERATION	DAYS	SCIENTIST
91	18 Jan.–30 April	Equalant I, South America	103	G. Metcalf
92	7–15 May	Norlantic Shipyard, N.B.	- -	- - - - -
93	4–22 June	Bermuda	19	A. Voorhis
94	25–30 June	1,000 Fathom Curve	6	R. Conover
95	8–17 July	South of Nantucket	10	R. Walden
96	22–25 July	Nantucket Sound	4	F. Webster
97	1 Aug.–3 Sept.	Barbados	39	M. Garstang
98	7 Sept.–4 Oct.	Barbados	26	V. Worthington
99	11 Oct.–4 Nov.	Bahamas	25	J. Barrett
100	5 Nov.–12 Nov.	Bahamas	8	P. Sachs
101	18 Nov.–6 Dec.	Bermuda	19	N. Fofonoff
102	10–14 Dec.	Gulf of Maine	5	R. Conover

GOSNOLD — Days at Sea–174 — Total Miles Sailed–22,100

CRUISE	DATES	AREA OF OPERATION	DAYS	SCIENTIST
5	3–6 January	Gulf of Maine	4	R. Conover
6	9–25 January	Baltimore & Hudson Canyon	17	F. Mather
7	6 March	Gay Head	1	K. Emery
8	23–29 March	Norlantic Shipyard	- -	- - - - -
9	22–24 April	Race Point	3	M. Mullin
10	26 April	Local	1	K. Emery
11	30 April	Local	1	K. Emery
12	2–7 May	Local	6	K. Emery
13	9–14 May	Local	6	K. Emery
14	21–23 May	Gulf of Maine	3	R. Conover
15	25–30 May	Block Island	6	D. Bumpus
16	11 June	Local	1	E. Uchupi
17-18	12–30 June	Bay of Fundy	19	E. Uchupi
19	1–4 July	Block Island	4	D. Bumpus
19	11–13 July	Block Island	3	D. Bumpus
20	16 July	Local	1	K. Emery
21	29 July–2 Aug.	Nauset Light	5	R. Siever
22	5–17 August	Gulf of Maine	12	K. Emery
23	19–22 August	Nantucket	4	D. Bumpus
24	24 Aug.–4 Sept.	Gulf of Maine	11	J. Hulsemann
25	7–10 Sept.	Block Island	4	D. Bumpus
26	17–20 Sept.	Cape Cod Bay	4	M. Mullin
27	21 Sept.–28 Sept.	Cape Cod Bay	8	P. Welander
28	3–6 October	Continental Shelf	4	R. Pratt
29	8–27 October	Continental Shelf	14	R. Pratt
30	4–5 November	Gulf of Maine	2	S. Haq
31	13 November	Gay Head	1	K. Emery
32	15 November	Tarpaulin Cove	1	R. Chase
33	23 Nov.–20 Dec.	Florida Coast	28	K. Emery

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No. 1381. E. B. KRAUS. The Diurnal Precipitation Change over the Sea. *Jour. Atmos. Sci.,* Vol. 20, No. 6, pp. 551-556. 1963.

No. 1382. D. K. LILLY and J. S. TURNER. The Carbonated-Water Tornado Vortex. *Jour. Atmos. Sci.,* Vol. 20, No. 5, pp. 468-471. 1963.

No. 1383. E. R. BAYLOR and W. H. SUTCLIFFE, JR. Dissolved Organic Matter in Seawater as a Source of Particulate Food. *Limnol. and Oceanogr.,* Vol. 8, No. 4, pp. 369-371. 1963.

No. 1384. MAX BLUMER, MICHAEL M. MULLIN and DAVID W. THOMAS. Pristane in Zooplankton. *Science,* Vol. 140, No. 3570, p. 974. 1963.

No. 1385. K. O. EMERY and CARL J. GEORGE. The Shores of Lebanon. *Amer. Univ., Beirut, Lebanese Republic, Misc. Papers in the Nat. Sci.,* No. 1, pp. 1-10. 1963.

No. 1386. MELVIN E. STERN. Trapping of Low Frequency Oscillations in an Equatorial "Boundary Layer". *Tellus,* Vol. 15, No. 3, pp. 246-250. 1963.

No. 1390. FERRIS WEBSTER. A Preliminary Analysis of Some Richardson Current Meter Records. *Deep-Sea Res.,* Vol. 10, No. 4, pp. 389-396. 1963.

No. 1396. JOHN REITZEL. A Region of Uniform Heat Flow in the North Atlantic. *Jour. Geophys. Res.,* Vol. 68, No. 18, pp. 5191-5196. 1963.

No. 1397. E. J. KUENZLER, R. R. L. GUILLARD and N. CORWIN. Phosphate-Free Sea Water for Reagent Blanks in Chemical Analyses. *Deep-Sea Res.,* Vol. 10, No. 6, pp. 749-755. 1963.

No. 1399. WILLIAM D. ATHEARN. Bathymetry of the Straits of Florida and the Bahama Islands. Part II. Bathymetry of the Tongue of the Ocean, Bahamas. *Bull. Mar. Sci., Gulf and Caribbean,* Vol. 13, No. 3, pp. 365-377. 1963.

No. 1400. ROBERT E. KNOWLTON and JAMES M. MOULTON. Sound Production in the Snapping Shrimps *Alpheus (Crangon)* and *Synalpheus. Biol. Bull.,* Vol. 125, No. 2, pp. 311-331. 1963.

No. 1401. R. BERNSTEIN and C. O. BOWIN. Real-Time Digital Computer Acquisition and Computation of Gravity Data at Sea. *Inst. Electrical and Electronic Engineers, Transactions on Geoscience Electronics,* Vol. GE-1, No. 1, pp. 2-10. 1963.

No. 1407. GEORGE D. GRICE. Deep Water Copepods from the Western North Atlantic with Notes on Four Species. *Bull. Mar. Sci., Gulf and Caribbean,* Vol. 13, No. 4, pp. 493-501. 1963.

No. 1410. ARTHUR K. SAZ. Antibiosis in sea water. *Iowa State Jour., Sci.,* Vol. 38, No. 1, pp. 75-81. 1963.

No. 1412. HAROLD L. BURSTYN. Galileo and the Earth-Moon System: Reply to Dr. Aiton. *Isis,* Vol. 54, Part 3, No. 177, pp. 400-401. 1963.

No. 1416. KUNI HULSEMANN and GEORGE D. GRICE. A New Genus and Species of Bathypelagic Calanoid Copepod from the North Atlantic. *Deep-Sea Res.,* Vol. 10, No. 6, pp. 729-734. 1963.

No. 1417. D. W. MOORE. Rossby Waves in Ocean Circulation. *Deep-Sea Res.,* Vol. 10, No. 6, pp. 735-747. 1963.

No. 1432. BOSTWICK H. KETCHUM. Some Biological Characteristics of the Marine Environment. *Great Lakes Res. Div., Univ. Michigan Publ.,* No. 10, pp. 236-244. 1963.

No. 1487. ARTHUR R. MILLER. Physical Oceanography of the Mediterranean Sea: a Discourse. *Rapp. Proc. Verb., Réunions, Comm. Int. Expl., Mer Méditerranée,* Vol. 17, No. 3, pp. 857-871. 1963.

Visitors from Abroad 1963

CHRISTIEN AGARATE
Sorbonne University, Paris

EIZO ASAHINA
Hokkaido University, Sapporo, Japan

ANTONIO BALLESTER
Estacion de Investigaciones Marinas de Margarita, Margarita Island, Venezuela

GILBERT W. BANE
University of Puerto Rico

P. A. BARKER
Naval Research Laboratory, Auckland, New Zealand

BRIAN McK. BARY
University of British Columbia, Vancouver, Canada

JOHN R. BEERS
Bermuda Biological Station

ADAM-BEN-TUVIA
Sea Fisheries Research Station, Haifa, Israel

ERIK BERTELSEN
Danish Institute for Fishery and Marine Research, Charlottenlund, Denmark

BERT BOLIN
University of Stockholm, Sweden

FRANCIS BRETHERTON
Cambridge University, England

B. B. BROCK
Anglo American Corporation, Johannesburg, South Africa

MME. MARIE CLAIR BUSNEL
Laboratoire d'Acoustique Animale, Jouy-en-Josas, France

BERNARD CALLAME
La Station Océanographique, La Rochelle, France

DONALD H. CARLISLE, JR.
University of Toronto, Canada

HENRY CHARNOCK
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A. MØLLER-CHRISTENSEN
Marine Biological Laboratory, Copenhagen University, Helsingor, Denmark

MALCOLM CLARKE
National Institute of Oceanography, Wormley, Godalming, England

DENNIS J. CRISP
Marine Biology Station, Federated University of Wales, Anglesey, North Wales

ERIK DAHL
Zoologiska Institutionen, Lund, Sweden

R. DAVILA
University of San Marcos, Lima, Peru

WM. H. DAWBIN
Zoology Department, University of Sydney, N.S.W., Australia

J. DEBYSER
Institut Français du Petrole, Paris, France

F. W. REYSENBACH DE HAAN
Lutherian Hospital, Endhoven, Netherlands

HENRI DE LAUZE
Centre National de la Recherches Scientifique, Paris, France

PAUL DESCHAMPS
Centre de Recherches et d'Etudes Océanographiques, Paris, France

PIERRE DESCHAMPS
Centre de Recherches et d'Etudes Océanographiques, Paris, France

PHILIP G. DRAZIN
Bristol University, Bristol, England

E. K. DUURSMA
Institute of Sea Research, Den Helder, Netherlands

S. N. DWINEDI
Institut Scientifique et Technique des Pêches Maritimes, France

JENS EGGVIN
Fiskeridirektoratets Havforskningsinstitutt, Bergen, Norway

INGVALD ENGELSEN
Saclant, La Spezia, Italy

ERIK ERIKSSON
Institute of Meterology, Stockholm, Sweden

W. L. FORD
Defence Research Board, Ottawa, Ontario

PETER FOXTON
National Institute of Oceanography, Wormley, Godalming, England

F. C. FRASER
British Museum (N.H.), London, England

ULF FRIBERG
Karolinska Institute, Stockholm, Sweden

A. S. FURUMOTO
Chaminade College, University of Hawaii

DHIRENDRANATH GANGULY
Calcutta University, India

DAVID GEORGE
Dalhousie University, Halifax, Canada

PERCIVAL GIDEON
University of Liberia, Monrovia, Liberia, West Africa

HANS HAMMERGREN
Meterological Institute, Stockholm University

S. MAZHAR HAQ
University of Karachi, Karachi, Pakistan

IIDA HAYATO
Hakodate Marine Observatory, Hokkaido, Japan

M. N. HILL
University of Cambridge, England

TAKAO HORIGUCHI
Port & Harbor Technological Research Institute, Yokosuka, Kanagawa, Japan

TADAYOSHI ICHIHARA
Whales Research Institute, Tokyo

G. Jobert
University of Paris, France

S. Krishnaswamy
University of Madras, Madras, India

Georges Kulbicki
Society National Petroleum Anonymous, Paris, France

Paul H. LeBlond
University of British Columbia, Vancouver, Canada

O. Leenhardt
Musée Océanographique, Monaco

C. B. Lister
University of Cambridge, England

J. P. Lonergan
Royal Australian Navy Experimental Laboratory

Silva Lopez
University of Mexico

Achie Sudiarti Machmat
Indonesia

C. R. Mann
Bedford Institute of Oceanography, Halifax, Nova Scotia

L. Harrison Matthews
Zoological Society, London, England

Pierre Mauffette
École Polytechnique, Montreal, Canada

Gerald Müller
Institüt für Meereskunde, Kiel

A. D. Mutch
Falconbridge Nickel Mines Ltd., Toronto, Canada

G. Needham
Bedford Institute of Oceanography, Dartmouth, Nova Scotia

Masaharu Nishiwaki
Whales Research Institute, Tokyo, Japan

Arne Norrevang
Anatomical Institute, University of Denmark, Copenhagen

Svante Oden
International Meterological Institute, University of Stockholm, Sweden

Hideo Omura
Whales Research Institute, Tokyo, Japan

Johan Onnerod
Norwegian Institute for Water Research, Blindern, Norway

O. H. Oren
Sea Fisheries Research Station, Jerusalem, Israel

Bernard Pelletier
Geological Survey, Ottawa, Canada

Sarwono Prawirohardjo
Indonesian Council for Sciences and the University of Indonesia

C. H. B. Priestley
Melbourne, Australia

Michael Reeves
University of Southampton, England

Basile Roufogalis
Research Center of the Royal Hellenic Navy, Salamis, Greece

Wolfgang Schott
Landesamt für Bodenforschung, Hanover, W. Germany

G. Seidler
Institut für Meereskunde, Kiel, Germany

Bruno Shreiber
Parma, Italy

A. J. Southward
Plymouth Laboratory of the Marine Biological Association of the U.K., Plymouth

E. C. Southward
Plymouth Laboratory of the Marine Biological Association of the U.K., Plymouth

Patrick Squires
Commonwealth Scientific and Industrial Research Organization, Sydney, Australia

Heinz Steinitz
Hebrew University of Jerusalem

Paul Tchernia
Laboratoire d'Océanographie Physique du Museum National d'Histoire Naturelle, Paris

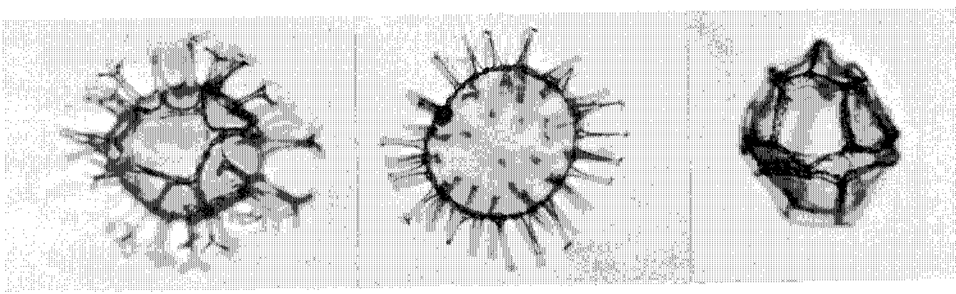
W. H. Dudok van Heel
Netherlands Institute for Sea Research, Den Helder, Netherlands

H. Weidemann
Deutsches Hydrographisches Institut, Hamburg, W. Germany

Wolfgang Wieser
Zoologisches Institut, Universität, Wien, Austria

Georg With
Stockholm

(See also lists of Fellowships and Visiting Committees)



Fossil dinoflagellates from the Quaternary of the Yucatan basin.

Bottom fauna collected at sea.

Grants and Fellowships

The following persons were awarded grants or fellowships during 1963:

NEIL ANDERSON
Massachusetts Institute of Technology

STUART D. ANDERSON
Harvard University

ANTHONY J. BARR
North Carolina State College

JOHN W. BORN
Ohio State University

RICHARD C. BROWER
Harvard University

ROBERT J. BRYNE
University of Chicago

RONALD BUCHANAN
University of British Columbia

JOHN F. CAMPBELL
University of Hawaii

GLENN A. CANNON
Drexel Institute of Technology

DONALD H. CARLISLE, JR.
University of Toronto

RICHARD L. CHASE
Princeton University

JASON K. S. CHING
Pennsylvania State University

NATHAN E. CLARK
Massachusetts Institute of Technology

ROBERT C. CLARK, JR.
Harvey Mudd College

ANTON M. DAINTY
University of Edinburgh, Scotland

JAMES A. DOUTT
California Institute of Technology

EARL C. EMERY
Boston University

ROBERT T. EMMET
Colby College

THEODORE D. FOSTER
Scripps Institute of Oceanography

GRAHAM S. GIESE
University of Rhode Island

ROSS R. GRUNWALD
South Dakota School of Mines and Technology

GABRIEL J. GUTMAN
University of Wisconsin

DAVID HABESHAW
University of Edinburgh, Scotland

RICHARD L. HAEDRICH
Harvard University

U. Theodore Hammer
University of Saskatchewan

J. A. Hellebust
University of Toronto

R. Hide
Massachusetts Institute of Technology

John C. Hoffman
Alfred University

Hartley Hoskins
University of Chicago

L. J. Howard
Massachusetts Institute of Technology

Alan Ibbetson
Massachusetts Institute of Technology

Carl G. Jockusch, Jr.
Swarthmore College

Robert E. Johnson
Wesleyan University

Hideo Kawai
Tohoku Regional Fisheries Laboratory, Japan

R. H. Kraichnan
New York University

Paul H. LeBlond
University of British Columbia

Jia D. Lin
University of Connecticut

Karen J. Lucas
Syracuse University

William S. Maddux
Princeton University

Lorenz Magaard
University of Kiel, Germany

Christopher C. Mathewson
Case Institute of Technology

Edward C. Monahan
Massachusetts Institute of Technology

D. W. Moore
Bristol University, England

Carl F. Morey
University of Rhode Island

Alvin J. Miller
Massachusetts Institute of Technology

Eric L. Mills
Yale University

Andrew J. Nalwalk
University of Pittsburgh

Alvin Nason
Johns Hopkins University

Richard T. Nowak
Massachusetts Institute of Technology

D. E. Osterbrock
University of Wisconsin

Louis D. Quin
Duke University

John Reigle
Rensselaer Polytechnic Institute

Peter B. Rhines
Massachusetts Institute of Technology

Donald C. Rhoads
University of Chicago

Michel Roberson
University of Kansas

Robert E. Rodstrom
Massachusetts Institute of Technology

F. Elwood Root
Massachusetts Institute of Technology

Cläes G. H. Rooth
University of Stockholm, Sweden

Stephen Rosencrans
Massachusetts Institute of Technology

Gregory N. Ruppert
Purdue University

James E. Seiple
Toledo University

Raymond C. Seitz
Johns Hopkins University

J. Dungan Smith
Brown University

Robert T. Smythe
Oberlin College

E. A. Spiegel
New York University

Robert F. Stein
Columbia University

Bernard Saint-Guily
Laboratory of Oceanography, Paris, France

John D. Taylor
University of Arkansas

Hendrikus W. Tinkelenburg
Massachusetts Institute of Technology

David W. Thomas
Massachusetts Institute of Technology

Alar Toomre
Massachusetts Institute of Technology

J. S. Turner
Commonwealth Scientific and Industrial
Research Organization, Australia

J. H. van Andel
Scripps Institute of Oceanography

Philip Vollmer
Hiram College

David Wall
University of Sheffield, England

Charles P. Warr
Vanderbilt University

John P. Wexler
Hobart College

James R. Wheatley, Jr.
East Carolina College

John Woodside
Queen's University, Canada

W. Redwood Wright
University of Rhode Island

John Woodcock
Lawrence High School,
Falmouth, Massachusetts

Michael Yates
Harvey Mudd College

Scientific Departments and Supporting Services Personnel

Paul M. Fye	Director
Bostwick H. Ketchum	Associate Director for Biology and Chemistry
David D. Scott	Assistant Director for Administration

The following were in the employ of the Institution for the twelve-month period ending December 31, 1963 (an asterisk indicating part-time throughout the year):

Applied Oceanography

Andersen, Nellie E.
Barstow, Elmer M.
Baxter, Lincoln II
Bradley, Mabel D.
Brockhurst, Robert R.
Chute, Edward H.
Cummings, Margaret L.
Erlanger, George L.
Fofonoff, Nicholas P.
Gifford, James E.
Graham, Russell
Hahn, Tineke
Hays, Earl E.
Howland, Myron P., Jr.
*Jones, Maxine M.
Learnard, Henry H.
Lyon, Thomas P.
Mavor, James W., Jr.
Michael, Joseph C., Jr.
Morrill, Duncan E.
Owen, David M.
Rainnie, William O., Jr.
Reese, Mabel M.
Sharp, Arnold G.
Shodin, Leonard F.
Shultz, William S.
Stimson, Paul B.
Swinhart, Orrin L.
Walden, Robert G.
Walsh, Joseph B., Jr.
Webb, Douglas C.
Wilkins, Charles H.

Biology

Bartlett, Martin R.
Baylor, Edward R.
Breivogel, Barbara B.
Chadwick, Constance W.
Chin, Edward
*Clarke, George L.
Conover, Robert J.
*Conover, Shirley M.
Corwin, Nathaniel
Douglass, Jane C.
*Fraser, Grace C.
Grice, George D., Jr.
Guillard, Elizabeth D.
Guillard, Robert R. L.
Hampson, George R.
Hessler, Robert R.
Hulburt, Edward M.
Kahler, Yolande A.
Kanwisher, John W.
Kuenzler, Edward J.
Laird, John C.
Mather, Frank J., III
McGill, David A.
Menzel, David W.
Mogardo, Juanita A.
Perras, James P.
Renshaw, Thomas H.
Rogers, M. Dorothy
Rose, Charles L.
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.
Valois, Frederica W.
Watson, Margaret E.
Watson, Stanley W.
Wilson, Esther N.
Yentsch, Charles S.

Chemistry and Geology

*Anderson, Neil R.
Athearn, William D.
Blumer, Max
Bowen, Vaughan T.
Burke, John C.
Carey, Francis G.
†Casey, Donald J.
Caron, Henri L.
Clarner, John P.
Daley, Marcia M.
Efinger, Gerald H.
Emery, Kenneth O.
Fitzgerald, William F.
Foley, Robert
*Giese, Graham S.
Harriss, Shirley W.
†Hathaway, John C.
Hayes, Carlyle R.
Hulsemann, Jobst B.
McCormack, Eileen M.
Morris, Robert E.
Noshkin, Victor E., Jr.
Pratt, Richard M.
Sachs, Peter L.
Sass, Jeremy
†Schlee, John S.
Siegel, Alvin
*Sugihara, Thomas T.
†Tagg, A. Richard
Tasha, Herman J.
†Trumbull, James V. A.
Uchupi, Elazar
Zeigler, John M.

† Member of U. S. Geological Survey assigned for work at the Woods Hole Oceanographic Institution.

Geophysics

Backus, Richard H.
Bergstrom, Stanley W.
Bowin, Carl O.
Broadbent, Alice G.
Broughton, Jane F.
Bunce, Elizabeth T.
Cain, Henry A.
Carter, Alwyn L.
Caulfield, David D.
Coleman, Vernon E.
Dow, Willard
Dunkle, William M., Jr.
*Gallagher, Gloria S.
Grant, Carlton W., Jr.
Hall, John K.
Hays, Helen C.
Hersey, John B.
Hess, Frederick R.
Johnston, Alexander T.
Jones, Barbara A.
Knott, Sydney T., Jr.
Mellor, Florence K.
Mizula, Joseph W.
Morehouse, Clayton B.
Perkins, Henry T.
Peterson, Jane M.
Poole, Stanley E.
Rhoads, Sandra S.
*Roberts, Helen M.
*Schevill, William E.
Senefelder, Lynne M.
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.
Anastasi, Ronald J.
*Arons, Arnold B.
Bailey, Charles B.
Barbour, Rose L.
Barrett, Joseph R., Jr.
Bradshaw, Alvin L.
Bruce, John G., Jr.
Bumpus, Dean F.
Chase, Joseph
Day, C. Godfrey
Densmore, C. Dana
Frank, Winifred H.
Fuglister, Frederick C.
Hays, Betty C.
Houston, Leo C.
Metcalf, William G.
Miller, Arthur R.
Munns, Robert G.
Pacheco, Marguerite E.
Parker, Charles E.
Phillips, Helen F.
Randall, Vivian H.
Rounbehler, David P.
Schleicher, Karl E.
Schroeder, Elizabeth H.
Soderland, Eloise M.
Stalcup, Marvel C.
Volkmann, Gordon H.
Voorhis, Arthur D.
Wagner, Donald P.
Warren, Bruce A.
Webster, T. Ferris
Whitney, Geoffrey G., Jr.
Worthington, L. Valentine

Theoretical Oceanography and Meteorology

Alexander, Robert M.
Armstrong, Harold C.
Blanchard, Duncan C.
Bunker, Andrew F.
Chaffee, Margaret A.
Frazel, Robert E.
Heinmiller, Robert H.
Iselin, Columbus O'D.
Kraus, Eric B.
Levine, Joseph P.
Ronne, F. Claude
Saunders, Peter M.
Spencer, Allard T.
Stern, Melvin E.
Stevens, Raymond G.
Veronis, George
Webster, Jacqueline K.

Administrative and Service Personnel

Allen, Norman T.
Anders, Wilbur J.
Backus, Harold
Backus, Jeanne M.
Bard, Wallace R.
Behrens, Henry G.
Blomberg, Lennert S.
Bodman, Ralph H.
Bowman, Warren O.
Brennan, John
Bryant, Edwin T.
Bujalski, Cleone C.
Burke, John E.
Cabral, John P.
Campbell, Eleanor N.
Carlson, Alfred G.
Carlson, Eric B.
Carlson, Ruth H. E.
Chalmers, Agnes C.
Christian, John A.
Condon, John W.
Cook, Harold R.
Conway, George E.
Corey, Norman
Crocker, Marion W.
Day, Joseph V.
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 E.
Grant, Carlton W., Sr.
Hahn, Jan
Hatzikon, Kaleroy L.
Henderson, Arthur T.
High, Carl A.
Hodgkins, Harry L.
Hodgson, Sloat F.
Hunt, Otis E.
Ingram, Ruth C.
Innis, Charles S., Jr.
Jenkins, Delmar R.
Johnson, Harold W.
Kania, Martha L.
King, Una T.
Lane, Egbert B.
LeBlanc, Donald F.
MacKillop, Harvey
McGilvray, Mary K.
McHardie, James
Merrill, Emily B.
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 A.
Reis, Janice A.
Robbins, Pamela
Rossby, Harriet A.
Rudden, Robert D., Jr.
Simons, Cecelia M.
Slabaugh, Luther V.
Solberg, Otto
Souza, Thomas A.
Spooner, Charles E.
Stanbrough, Jess H.
Stansfield, Richard
Stimpson, John W.
*Sullivan, James R.
Teixeira, Morris
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
Baker, William R.
Barboza, Andrew
Bazner, Kenneth E.
Betterly, Robert
Botas, Walter D. G.
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.
Edwards, Richard S.
Ewing, William R., Jr.
Halpin, William T.
Hamblet, Dwight F.
Hiller, Emerson H.
Howe, Paul M.
Howland, Paul C.
Jefferson, Albert C.
John, Alfred C.
Karram, Calvin D.
Kay, J. Kevin
Kellner, Paul D.
Kostrzewa, John A.
Lambert, Joseph L.
Leiby, Jonathan
Mackey, Malcolm R.
Matthews, Francis S.
Moller, Donald A.
Montgomery, Earl C.
Morse, Joseph C.
Mosier, Craig R.
Mysona, Eugene J.
Palmieri, Michael, Jr.
Pennypacker, Thomas R.
Pierce, George E.
Pierce, Samuel F.
Pike, John F.
Ribeiro, Joseph
Rose, Lawrence
Roy, Alfred J.
Seibert, Harry H.
Shields, William J.
Smith, William J.
Stires, Ronald K.
Thurston, Theodore G.
Tully, Edward J.
Wheble, John E.
White, William A.
Williams, George A.
Williamson, Harvey V.

Treasurer's Report

The accounts for the year 1963 have been audited by Lybrand, Ross Bros. & Montgomery.

The book value of endowment funds at December 31, 1963, was $4,104,494, of which $1,535,402 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 $6,339,189. Endowment fund investments and income received therefrom are summarized on page 63.

The plant fund accounts on the Balance Sheet reflect the balance of the changes resulting from the construction of the new research vessel and the new Laboratory of Marine Sciences, 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 $209,095 for the year ended December 31, 1963, compared with $191,875 the previous year. Endowment income includes $127 of parking lot income which represented a 0.4 per cent return on this investment and $2,994 on 38 Water Street which represented a 5.0 per cent return on this investment. The balance of the 38 Water Street income, amounting to $309, was transferred to endowment assets to amortize the cost of this property. The parking lot was available for outside parking on week ends only, as Institution personnel occupy all the space during the working week. Endowment income represented a return on endowment fund assets of 3.4 per cent at year-end market quotation, 5.4 per cent on book amount and 8.1 per cent on the contributed amount of the endowment fund.

Endowment income was allocated for 1963 operating expenses at the rate of 6 per cent of the book amount of original endowment funds, or $146,545. Of the balance of endowment income, $62,550, there was transferred to the income and salary stabilization reserve $61,235 and to Oceanographic Associates as income from investment of life memberships, $1,315.

The Institution's 1963 contribution to the Woods Hole Oceanographic Institution's Employees Retirement Trust amounted to $160,114.98.

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, 1963 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. We previously examined and reported upon the financial statements for the year ended December 31, 1962.

In our opinion, the accompanying statements (pages 60 and 61, inclusive) present fairly the financial position of Woods Hole Oceanographic Institution at December 31, 1963 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.

The supplemental schedules included in this report (pages 62 and 63, inclusive) although not considered necessary for a fair presentation of the financial position and results of operations, are presented primarily for supplemental analysis purposes. This additional information was obtained from the Institution's records and is, in our opinion, fairly stated in all material respects in relation to the basic financial statements taken as a whole.

Boston, Massachusetts
March 16, 1964

Lybrand, Ross Bros. & Montgomery

Balance Sheet as at December 31, 1963

ASSETS

Endowment Fund Assets:		
Investments:		
Bonds (market quotations $2,191,833)		$ 2,222,162
Stocks (market quotations $3,821,570)		1,556,546
Real estate		90,792
		3,869,500
Cash		234,994
		4,104,494
Plant Fund Assets (Note):		
Laboratory plant and equipment		3,063,347
Vessels and equipment		5,700,697
Other property		287,523
Total plant		9,051,567
Plant funds advanced to current		494,751
		9,546,318
Current Fund Assets:		
Cash		180,336
Accounts receivable:		
U.S. Government	$ 227,372	
Other	9,832	237,204
Unbilled costs:		
U.S. Government	1,353,757	
Other	7,824	1,361,581
Supplies		47,570
Deferred charges		54,048
Plant funds advanced to current		(494,751)
		1,385,988
		$15,036,800

LIABILITIES

Endowment Funds:		
Unrestricted as to income	$2,100,000	
Unrestricted as to principal and income	47,672	$ 2,147,672
For upkeep of plant		419,420
Henry Bryant Bigelow Chair of Oceanography		2,000
Accumulated net gain on sales of investments		1,535,402
		4,104,494
Plant Funds:		
Invested in plant (including $4,828,000 for construction of Atlantis II, title to which is conditional upon its continued use for oceanographic research)		9,051,567
Unexpended:		
Fund for acquisition of capital assets		378,770
General plant and equipment reserve		115,981
		9,546,318
Current Liabilities and Funds:		
Accounts payable and accrued expenses		358,735
Contribution payable to employees' retirement plan and trust		160,115
Unexpended balances of gifts and grants for research:		
Government	154,264	
Other	99,127	253,391
Reserves:		
Income and salary stabilization reserve	459,591	
Working capital and contingency reserve	154,156	613,747
		1,385,988
		$15,036,800

NOTE — Depreciation is provided on plant assets other than vessels and the Laboratory of Marine Science, at annual rates of 2% on buildings and 5% to 33⅓% on equipment. The amount provided is credited to general plant and equipment reserve.

Comparative Statement of Operating Expenses and Income

Years Ended December 31, 1963 and 1962

	1963	1962
Operating Costs and Provisions:		
Direct costs of research activity:		
Salaries and wages	$2,065,893	$1,689,864
Vessel operations (note)	2,078,184	1,238,568
Materials and services	3,602,686	3,282,433
Travel	256,951	217,087
	8,003,714	6,427,952
Indirect costs:		
General and administration (note)	484,371	741,459
Plant operations (note)	279,595	315,532
Miscellaneous	25,662	27,040
Other charges:		
Provision for working capital and contingencies	186,987	88,696
Plant additions, books and equipment		32,487
	$8,980,329	$7,633,166
Income:		
For sponsored research (including 1963 — $3,169,821, 1962 — $1,937,515 gifts and grants expended):		
For direct costs	7,909,001	6,335,490
For indirect costs	751,785	954,726
Fees for use of facilities	205,776	189,580
	8,866,562	7,479,796
Endowment income availed of:		
For institution research	94,713	92,462
For institution indirect costs	12,181	54,215
Miscellaneous	6,873	6,693
	$8,980,329	$7,633,166

NOTE—Vessel operations include in 1963 $316,000 of costs which were classified as general, administration and plant operations in 1962.

Statement of Changes in Funds

Year Ended December 31, 1963

	Endowment Funds	Plant Funds		Unexpended Balances of Gifts and Grants for Research (Note)	Reserves	
		Invested in Plant	Unexpended		Income and Salary Stabilization Reserve	Working Capital and Contingency Reserve
Balance, December 31, 1962	$3,710,160	$6,910,960	($ 246,065)	$ 803,939	$398,522	$117,848
Gifts and grants received	100,000		2,337,346*	2,911,208		
Endowment income					169,486	39,609
Net gain on sales of investments	300,998					
Additions from current year's operations:						
Provision for depreciation			139,260			
Provision for working capital, deferred maintenance and contingencies						186,987
Availed of for research costs				(3,169,821)	(106,894)	
Transferred to plant funds from working capital and contingency reserve and unexpended balance of gifts from Oceanographic Associates			400,000	(200,000)		(200,000)
Transferred to unexpended balance of gifts from Oceanographic Associates	(6,664)			8,164	(1,500)	
Invested in plant		2,018,956	(2,018,956)			
Capitalization of items expensed in prior years		126,723	(126,723)			
Prior years depreciation on items capitalized			9,889			
Cost of assets disposed of		(5,072)				
Miscellaneous additions (reductions)				(100,099)	(23)	9,712
Balance, December 31, 1963	$4,104,494	$9,051,567	$ 494,751	$ 253,391	$459,591	$154,156

*Includes $1,282,000 received on grant for design and construction of a research vessel and $1,055,000 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.

Direct Costs of Research Activity

Year Ended December 31, 1963

	Salaries and Wages	Vessel Operations	Materials and Services	Travel	Total
U.S. Government:					
Contracts	$1,434,199	$1,099,220	$2,321,886	$111,524	$4,966,829
Grants	585,842	933,958	1,150,564	135,771	2,806,135
Other sponsored research RESEARCH	11,660	41,230	78,484	4,663	136,037
Total direct costs of sponsored research	2,031,701	2,074,408	3,550,934	251,958	7,909,001
Institution research	34,192	3,776	51,752	4,993	94,713
Total direct costs of research	$2,065,893	$2,078,184*	$3,602,686**	$256,951	$8,003,714

*Includes costs of operating vessels ($316,000) which were classified as general, administration and plant operation expenses in prior years.

**Includes grants and fellowships:

Other sponsored research	$57,208
Institution research	22,241
	$79,449

General and Administration Expenses and Expenses for Plant Operation

Year Ended December 31, 1963

General Expenses:		
Staff benefits:		
Contribution to retirement plan		$ 12,442
Social security taxes		6,605
Employee health benefits		9,131
Group insurance		4,061
		32,239
Shop services		52,871
Administration Expenses:		
Salaries and wages	$246,650	
Insurance, travel, supplies and other	152,611	399,261
		$484,371
Plant Operation:		
Salaries and wages		$ 75,790
Contribution to retirement plan		5,580
Social security taxes		2,447
Provision for depreciation (credited to general plant and equipment reserve)		46,003
Other repair costs	31,306	
Heat, light and power	48,546	
Other	69,923	149,775
		$279,595

NOTE — In 1963 the portion of general, administration and plant operation expenses identifiable with marine operations were allocated to applicable projects as direct costs. This change resulted in a decrease in general, administration and plant operation expenses of $316,000.

Summary of Investments

As at December 31, 1963

	Book Amount	% of Total	Market Quotation	% of Total	Endowment Income
BONDS:					
Government	$ 941,492	24.3	$ 938,988	15.4	$ 26,426
Railroad	429,090	11.1	417,804	6.9	16,305
Public utility	347,036	9.0	331,724	5.4	15,065
Industrial	343,828	8.9	338,738	5.5	18,170
Financial and investment	160,716	4.1	164,579	2.7	8,456
Total bonds	2,222,162	57.4	2,191,833	35.9	84,422
STOCKS:					
Preferred	104,707	2.7	109,762	1.8	9,892
Common:					
Public utility	398,385	10.3	1,097,885	18.0	33,475
Industrial	701,141	18.1	1,953,084	32.0	57,300
Miscellaneous	352,313	9.1	660,839	10.8	20,885
Total common stocks	1,451,839	37.5	3,711,808	60.8	111,660
Total stocks	1,556,546	40.2	3,821,570	62.6	121,552
REAL ESTATE	90,792	2.4	90,792*	1.5	3,121
Total investments	$3,869,500	100.0	$6,104,195	100.0	$209,095

*At book amount.