WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts

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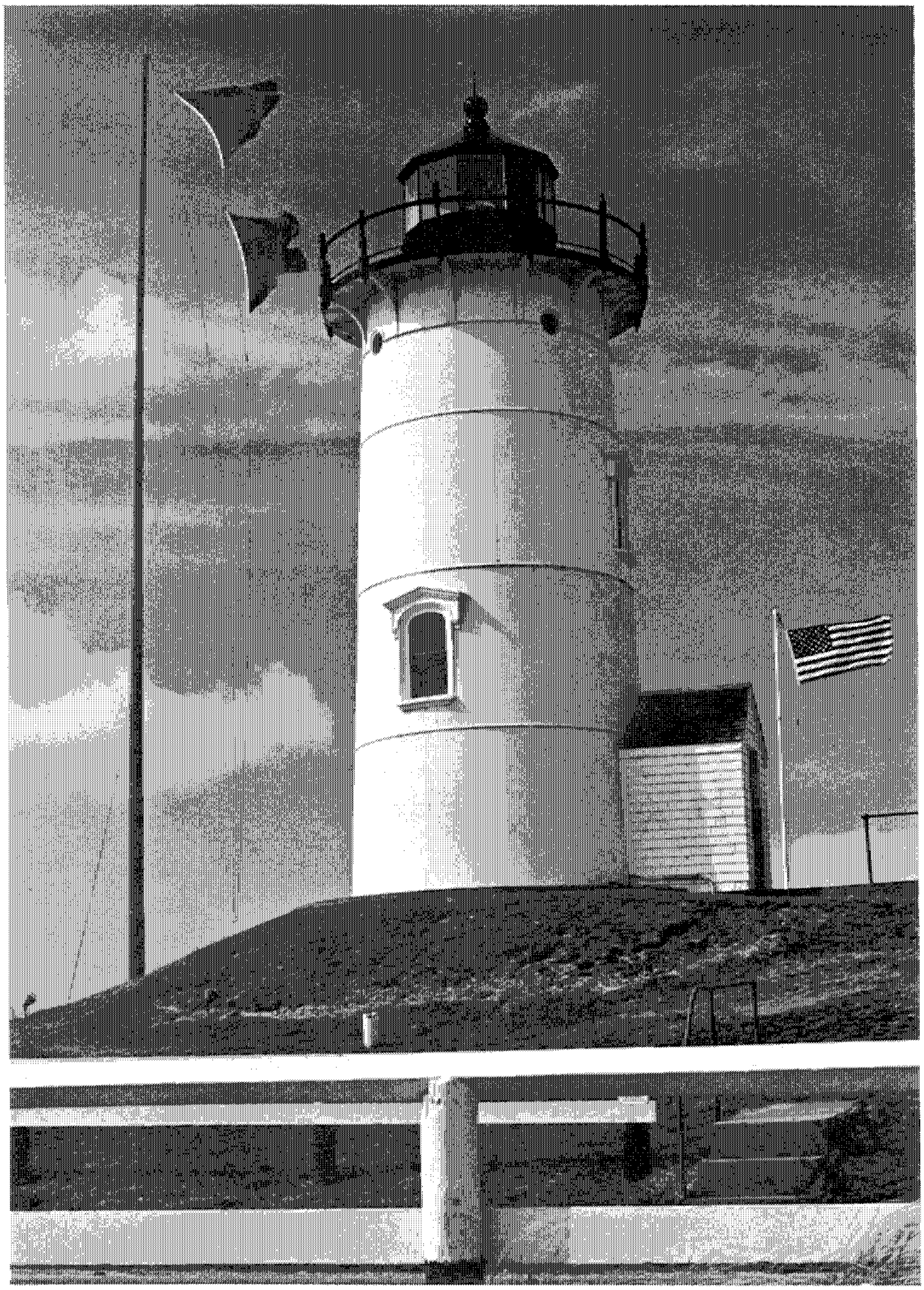

One of the '72 gales at Nobska Point KvdH

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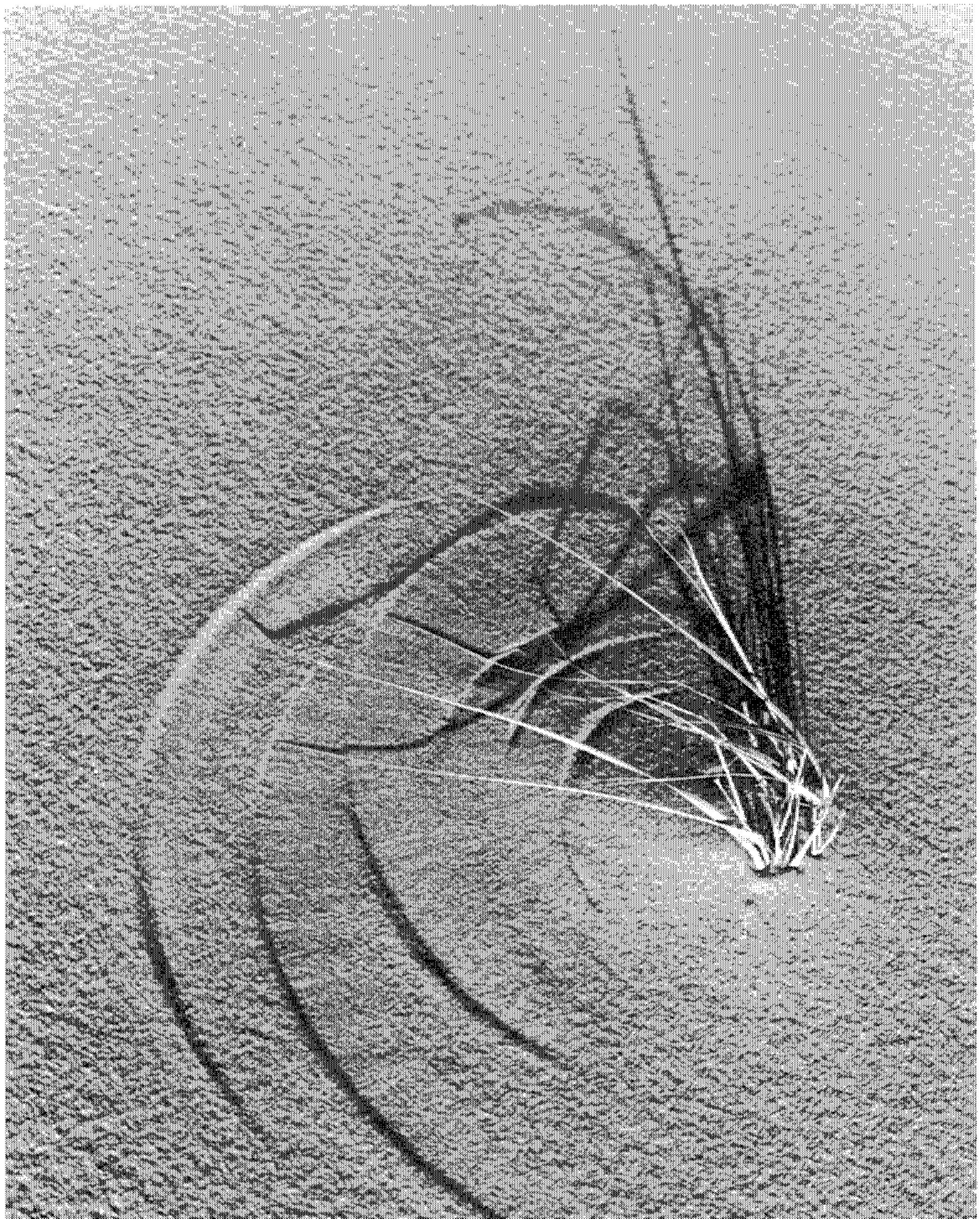


KvDH

Harlow Shapley

November 2, 1885 - October 21, 1972

Harlow Shapley was one of the original incorporators and trustees having been elected to both offices on 10 January 1930. An astronomer of world repute, he served as friend and adviser to the officers of the Institution for more than twenty-five years. The first president and first director frequently turned to him when selecting new members of the corporation or of the staff. His common sense and shrewd judgment of people combined with his forthright opinions were much needed and appreciated in the early days of the Institution. With his tremendous powers of concentration, no problem was too mundane for his consideration.

Although recognized by innumerable honorary degrees and other awards in astronomy, it is difficult to assess his contribution to oceanography, but it is clear that the science then in its infancy profited greatly through his frequent association with the small group who guided the Institution through the first ten years.

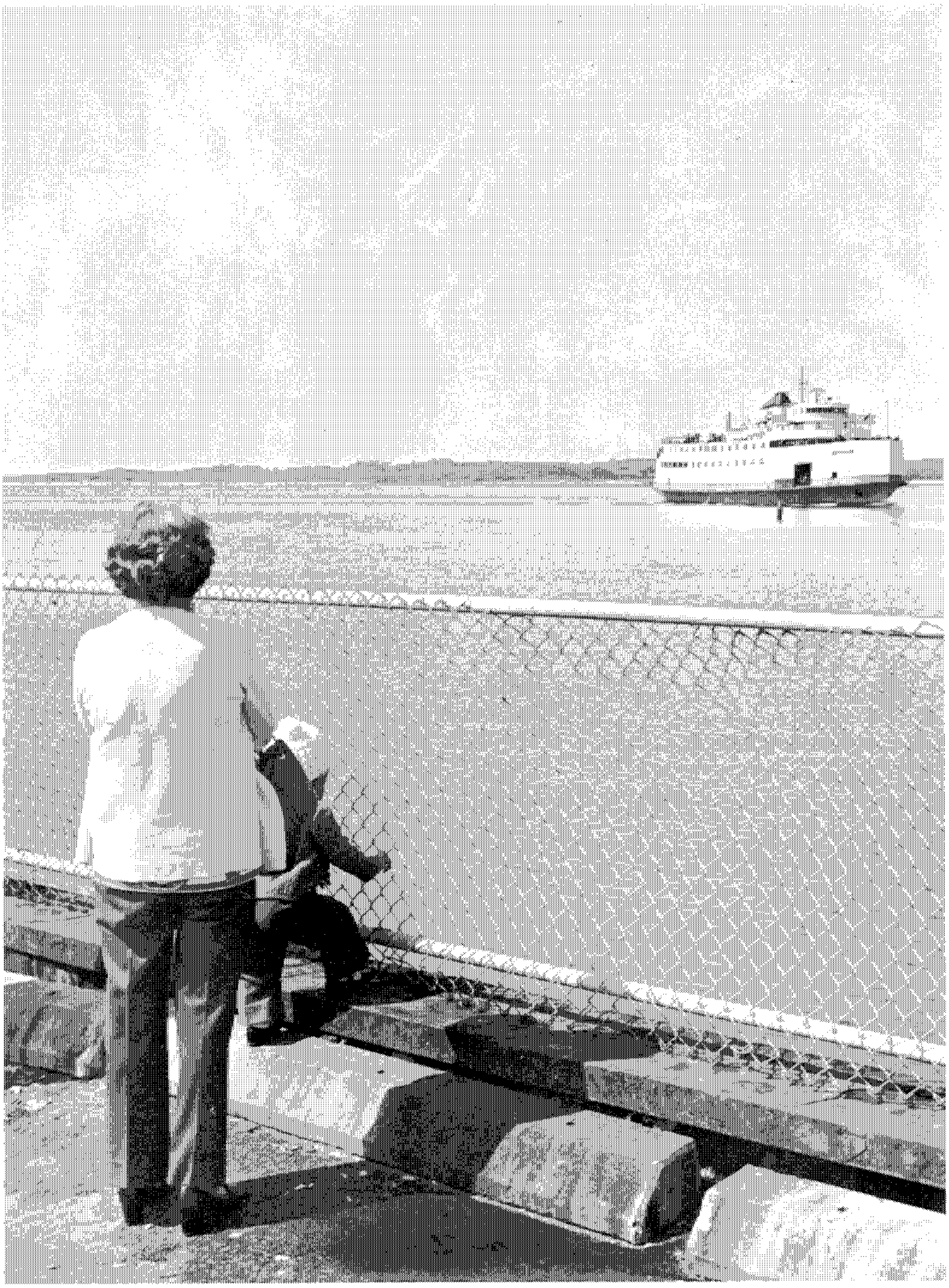
Professor Shapley received his Ph.D. from Princeton University. From 1914 to 1921, he was an astronomer at the Mt. Wilson Observatory, and then became both Director of the Harvard Observatory (1921 to 1952) and Paine Professor of Astronomy at Harvard University, where he remained until his retirement.

William Webster

December 6, 1900 - May 17, 1972

William Webster was elected a Member of the Corporation in 1961 and a Trustee of the Institution in 1964. From 1965 to 1967, he was a valued member of the Executive Committee of the Board of Trustees. His keen interest in Woods Hole was exemplified by a visit of several weeks which he made shortly after becoming a Trustee to familiarize himself with the Institution and its activities. In word and deed, he expressed his great interest in the Institution and its programs. His advice was sound and timely.

Mr. Webster, a graduate of the Naval Academy in 1920, served principally as a Naval Constructor until his resignation in 1928 to join the New England Electric System, from which he retired as Chairman in 1970. He brought atomic energy to New England by coordinating the activities of the regional electric companies which combined to build the first nuclear electric generating plant in the area at Rowe, Massachusetts. In 1967, he received a citation from the Atomic Energy Commission primarily for this achievement. Earlier (1962) he had received the Edison Medal at the Annual Convention of the Edison Electric Institute, the industry's highest honor. During and after World War II, he also filled a succession of national scientific advisory positions.



Homeward bound from Nantucket.

DIRECTOR'S REPORT

Planning for the Future

It is essential that an institution attempt to chart its own future and to influence its destiny. The task is especially crucial for a research institution, and also especially difficult, because our "products" are intrinsically future-oriented. Research, after all, is a deliberate process which seeks to know that which will be most worth knowing in the future. Planning, therefore, involves not only making judgments about the future directions and needs of the larger society but also requires judgments about the most promising scientific directions.

The process by which the Institution's future is shaped is a complex one and involves many participants. The individual scientist's choice of a research problem, decisions regarding new appointments, and planning for new facilities all represent detailed actions which in large part determine the future institution. But there must be processes which can provide the broad background against which such decisions can be rationally made. Sometimes these processes are *ad hoc* studies involving joint studies by our Trustees and Staff, such as led to our decision a few years ago to have a formal educational program, or studies made within the Staff such as our planning for ship needs or modifications to our personnel policies. We also have had a regular practice of setting up Visiting Committees whose reports have had a significant effect on shaping our future plans, particularly in determining new fields for research activity.

Another effort which has proved most useful to us in our planning for the future has been a series of Staff Council "retreats". These are planned occasions where the senior administrators — away from routine interruptions — deliberate together about future problems facing oceanography and our Institution. I should like to report here on these meetings and on some of the issues which have concerned us most recently.

The Staff Council, which consists of the seven members of the Directorate and the five Department Chairmen, have had four such retreats since 1967. For each session, we have invited two or three distinguished guests, not only so we could share their wisdom, but also so we could be sure that our perspective was raised above the short range administrative issues of the Institution. These guests representing both Corporation members and imaginative leaders in the field of oceanography have included: Arnold B. Arons, Hudson Hoagland, H. Burr Steinbach, Roger Revelle, the late Wilbert McL. Chapman, the late Milner B. Schaefer, Frank Press, John D. Isaacs, John V. Byrne, Werner A. Baum, Athelstan Spilhaus and Charles F. Adams. The settings for these meetings have been well removed from interruptions — the first two (1967, 1968) at White Cliffs in Plymouth, the most recent two (1972, 1973) on Nantucket.

The subjects discussed at these meetings have been wide-ranging, although a common theme has been an attempt to assess the most fruitful roles of oceanography in a changing world, and in turn to translate that assessment into possible responses of the Institution. Although such an assessment can never be made with clarity or finality, and certainly never with complete agreement, the resulting discussions have been worthwhile in helping to unify our perspective. Indeed, many of the discussions have borne fruit by organizational and policy changes or by the introduction of new programs.

The organizational policies which have guided our new educational program have stemmed from discussions at these meetings. It was specifically agreed upon, for example, that the formal educational program should be integrated in the maximum possible way into our research organization. Thus, the original idea of a "faculty" organized separately from our research staff was rejected as potentially devisive and contrary to a sound graduate program which should receive its vitality from the research activities of the Institution. Our Department Chairmen, as a result of this decision, have become leaders in both research and education. While this has increased their responsibilities, the resulting simplification of the administration of appointments, student financing, space and a host of other important details, as well as the unification of Institution goals which combine education and research, have made that decision a lasting and worthwhile one.

Other organizational changes have stemmed from these meetings. Our efforts in Geology and Geophysics were consolidated into a single department. A single Department of Physical Oceanography was formed by combining previously separated theoretical and experimental groups. A new Department of Ocean Engineering was formed to include the service engineering functions as well as the design of new instruments and techniques.

While we perhaps cannot trace the decision to establish a program in Marine Policy and Ocean Management directly to one of these meetings, it is clear that specific discussions three years prior to the start of the program on the impact of changes in the law of the sea, the geopolitics of marine affairs, the importance of understanding the economics of marine resources and the history of the marine sciences contributed to the concept of the program.

I believe it is significant that the character of the discussions at the more recent meetings in 1972 and 1973 have differed somewhat from the previous meetings in 1967 and 1968. The earlier meetings were more directed at internal organizational questions and the general frame of reference of the discussion was the marine sciences. The recent meetings have been broader in scope, more philosophical, and more challenging of our own assumptions. The discussions have dealt much more with public needs and priorities and how the Institution's efforts should best respond to and serve these needs.

This change in perspective reflects a changing attitude of both the public and the scientific communities about the social role of science. The '60's was a period of growth in the sciences and was based largely on the simple and straightforward faith that science was intrinsically good and that benefits would automatically flow from it. This simple faith no longer can sustain the scientific enterprise. We have more sophisticated weapons dedicated to deterrence but we still have war. We have been to the moon, but our cities are still in decay. We have wonder drugs and heart transplants, but many of our citizens do not have adequate health care. We have had economic growth, but we are undermining the quality of the environment. These realizations, as well as others, mean that the sciences of the '70's and '80's will be judged closely by their impact on the most pressing social questions. The issue, I believe, is not that people have lost faith in the power of science — indeed it is clear that most social problems need science for their solution — but that the public would like assurance that the full power of science is being most effectively directed to the problems of society.

There is substantial evidence that there are strong public pressures for science to be relevant to the needs of society. The day before our retreat of 1972 the President sent a message to Congress urging that American ingenuity be brought to bear on a host of national problems. His proposed goals ranged from new pollution-free sources of energy to reducing the loss of life and property from natural disasters, and he stressed the important role of science and technology in solving the problems of civilian society. Previously, we were keenly aware of the passage of the Mansfield amendment which restricted Navy research to mission-oriented goals, of the establishment of the Sea Grant program to foster the application of marine science to practical purposes and of the new National Science Foundation program of Research Applied to National Needs.

Our central theme for discussion at the 1972 retreat was the question of the response of the Institution to these increasing pressures for science to be "more relevant". Were we, in fact, neglecting our responsibilities in this matter? Were there new thrusts or changes in policy and program efforts demanded by the changing times?

These questions were not new ones for us. For some considerable time we had debated our role and organization in dealing with the question of environmental pollution. We had previously set up the Office of Environmental Quality under Dr. Ketchum in order to coordinate and to stimulate our efforts in this area. A review of our environmental research work showed that it was increasing at a rapid rate — not so much because it was deliberately planned as an organized effort, but rather it reflected a desire on the part of individual scientists to work on such problems as oil spills, the distribution of pesticides in the ocean and the effects of heavy metals on fish. One can draw from this a conclusion which should perhaps be obvious — scientists are not in fact isolated from the issues of the society at large, and scientists as much as anyone else want their efforts to be "useful".

We have observed how a larger share of the Federal oceanographic budget has been going into big inter-institutional programs, such as the study of the chemical constituents of the oceans (GEOSECS), the study of the dynamic movements of water within a large volume of the ocean (MODE) and the drilling of deep-sea sediments (JOIDES). These have been judged to be innovative and relevant and together with other "big programs" have consumed increasing amounts of money. We estimate that more than one-third of our effort has been going into such programs. Even though these put severe constraints on ship-scheduling, it was clear that brilliant people had been attracted to these programs which were doing a great deal of very valuable work.

A new management system of inter-institutional committees had arisen to sponsor these "big-science" projects. We judged that these have been excellent in initiating new programs but that they had an element of long-term instability and could create a situation wherein centralized control by Government agencies would become more likely. We considered it a real challenge to the Institution to assist in the development of management techniques which would stabilize and carry to successful completion such programs. The JOIDES inter-laboratory organization was one successful answer to this management problem and others should be invented.

Generally we felt that students and young scientists would inject a healthy degree of relevance; that we should not permit the "big programs" to consume all our facilities; that we should protect the loner who has bright ideas and the young scientist who does not wish to become a part of these programs; and that we should build competence in our staff by recruiting bright people who are excited about the relevant problems of today and tomorrow.

The theme of "relevance" continued at the last retreat in March 1973, although our specific focus was on the subject of Federal support to oceanography in the few years immediately ahead. Federal support to science, at least in the areas previously considered the "basic" sciences is diminishing. Oceanographic research, along with other sciences, will be affected in the years ahead. Specifically, construction funds for two new research ships in 1973 and 1974 have been eliminated and operating funds for ship operations will be cut by about twenty percent in 1974. This will require the laying up of ships in the national oceanographic fleet. For Woods Hole, we anticipate that both GOSNOLD and CHAIN must be retired or re-assigned and hope that our new ship can be built in time to partially fill the substantial gap which will be created.

The real issue is how such changes affect the future health of the marine sciences in the United States. The evidence on what will be happening to Federal programs is not sufficient at this time to draw clear conclusions. The challenge to the Institution of the immediate future is the wise allocation of our resources. We believe we must do our utmost to protect our most valuable asset — our people. This may mean substantial reduction in procurement of equipment and some reduction in ship use.

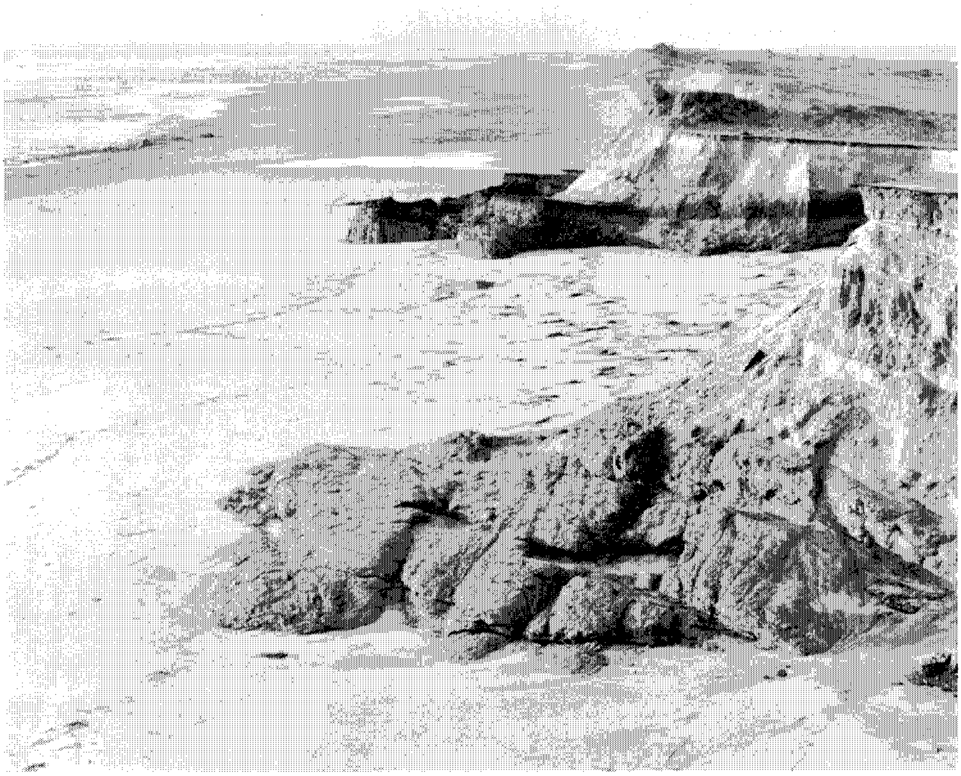
The discussions at our retreats have reinforced my own deeply held convictions that oceanographic research of the type and quality conducted by our Institution is by its very nature directly relevant to problems of the real world. Clearly there is a need for translators who can explain the worth of scientific investigations and for interpreters who can elucidate scientific findings for the users.

The re-evaluation of the role of science in solving society's problems which is taking place is, I believe, a very healthy one. Nevertheless, it is not free of substantial dangers. Some of these dangers are induced by the very semantics involved. The debate itself implies to some that past science has been irrelevant. There is a difference between a desire to have science more "relevant" than to say that scientists should only do research which seems to be relevant. The best fundamental science can never be irrelevant. On the other hand, uninspired and methodical efforts on programs which only seem to be relevant are doubly wasteful — such efforts neither solve the apparent problem nor do they learn something worth knowing.

The central thrust of science is the seeking of new ideas. It is to know things which are not now known. The practical challenges ahead will not be better served by ignoring this central driving force of science. We do not know all we need to know in order to solve society's problems — and indeed we never will. The new task is how do we, as a whole society, do better in putting our scientific knowledge to work.

Our most recent retreats have not diminished my confidence in the essential correctness of the central and historic thrust of the Institution, to increase our knowledge about the oceans and related environments. The oceans are crucial in sustaining civilized society and our ignorance of them is still vast. The task of understanding the oceans is clearly relevant to human needs. We must, however, expand our efforts to improve the translation of this understanding into specific public needs and continue to welcome the application of our particular skills and talents for the common good.

PAUL M. FYE



Staff and graduate students work together.

Report of the Dean of Graduate Studies

Under joint Woods Hole Oceanographic Institution/Massachusetts Institute of Technology auspices twenty-one degrees have now been awarded, eighteen doctorate and three ocean engineer degrees. With one exception, all are productively employed in marine fields including three in the Navy. Anticipated in 1973 will be eight more doctorates. Fulfillment of the requirements for these degrees will have taken an average of 4.7 years with a range of three to six years.

From a base of fifty in 1969, the number of applicants has more than quadrupled for the academic year 1972-73. This, even allowing for our growth, is a remarkable reversal of the national trend of declining graduate enrollment. Of the applicants last year, only twelve percent could be offered admission. Sixty percent accepted, again a favorable figure in terms of national trends. Analysis of admission-acceptance figures indicates that our competitors are primarily the University of California, San Diego and "Ivy League" schools.

Total enrollment, joint program and the Woods Hole Oceanographic Institution degree program, is stabilizing at about sixty-five. This appears to be its correct level, one dictated primarily by our concept of fitting junior scientists into a research atmosphere of active work being carried out by established scientists. Current enrollment includes twelve percent foreign nationals and twelve percent women. We continue to search for acceptable candidates from minority groups.

It is of interest that the majority of applicants address their inquiries to the Institution, reversing that situation that was evident in the early phases of the Joint Program. There has also been a steady increase in the number of students resident in Woods Hole with about half having headquarters here.

In terms of student support, the Institution continues to provide stipends from Institutional funds for the majority of students in residence at Woods Hole. However, steps have been taken to remove the distinction, in terms of duties and obligations of students, between research assistantships supported on grants or contracts and funds provided as fellowships. As students progress with thesis work, their support is transferred where possible to grants and contracts.

The National Science Foundation has a special program to provide expense support to graduate students doing meritorious thesis projects. Four of our students have applied for such support, three have received awards to date, with one proposal not yet acted upon.

Statistical data indicates a skeleton of successful growth but cannot convey the true form and substance of the program. Previously I have characterized our program as one of healthy ferment. I am happy to report that the yeastiness shows no signs of abatement. In our Education Programs booklet we state, "Fundamental to the education process at Woods Hole is the belief that the place for young people to learn to be good scientists is in an atmosphere of good science. . . . We start from the base of scientific enterprise, not from a base of transmitting knowledge as a teaching function." The Institution is a place in which to learn. These are good statements — implementation of a program to achieve the goals is a formidable problem. Funneling sixty students through an organized curriculum, a series of standard courses is a relatively easy job. Tailoring sixty degree programs for sixty individuals working with sixty other individuals presents problems not simply additive but probably expressed more aptly as 60^u problems where "u" is greater than one. One of the Visiting Committees characterized our programs with the comment, "The tutorial system is costly and the present plan of graduate training is unorthodox." With both statements we must agree and with enthusiasm. The system is costly and it is unorthodox but it has the great merit of inducing an active personal involvement on the part of students and staff alike. Student-originated subject offerings are uniquely adding to the program in a way that staff generated didactic courses would find it hard to equal. In addition, some superb teachers are contributing their efforts, both in working with the student originated courses and in more formally organized programs.

A very constructive recent development has been the formation of special curriculum committees, including student representation, in the geology-geophysics and chemistry areas. Preliminary reports are in, and, combined with reports from other areas in the future will provide a very sound base for the future planning of the overall program in somewhat more detail.

Students continue to be visible, vocal and helpful. Their organization continues in its fine informal fashion and the Visiting Scholars program, masterminded by the students, was again a success.

The several Visiting Committees met this year and all devoted considerable attention to the education program. Their reports contain wise and helpful comments which will serve well in future planning. All note the relatively unstructured nature of our program and all recommend continued scrutiny as to whether or not a more formalized pattern may be needed in the future. This is a wise caution; we cannot afford to let the rosy glow of a vision interfere with the devising of most appropriate pathways.

As in the past, Committee activities play an essential role in the program. The newly established Woods Hole Admissions Committee reviewed all the applications for admission to graduate study. From the ordered list of applicants, the Joint Program Committees made selections of those to whom admission was offered. This was a formidable task met with wisdom and effectiveness by all Committees concerned. Needless to say, selection of students is the only truly critical step in our educational process.

The Fellowship Committee reviews all applications from students other than the graduate degree applicants. This includes the Summer Fellowship Programs and the Postdoctoral Awards Program. All told, this involves the critical scrutiny of over four hundred applicants ranging from college students to postdoctoral scholars.

The Summer Fellowship Program has long enjoyed high favor with our staff. Students selected are, with rare exception, truly superior youngsters who bring to their work a refreshingly naive candor which makes them exciting to have around.

The Postdoctoral Award Program is somewhat younger, having its genesis upon obtaining funding from outside agencies. The results have been most impressive in terms of recruiting talented young Ph.D.'s into the field of oceanography. In some notable instances they have led to staff appointments at the Institution — having an individual on deck is a wonderful way of assessing abilities and potentialities. Hopefully, outside funding will be found again, meanwhile the continuation of the program has been a wise decision.

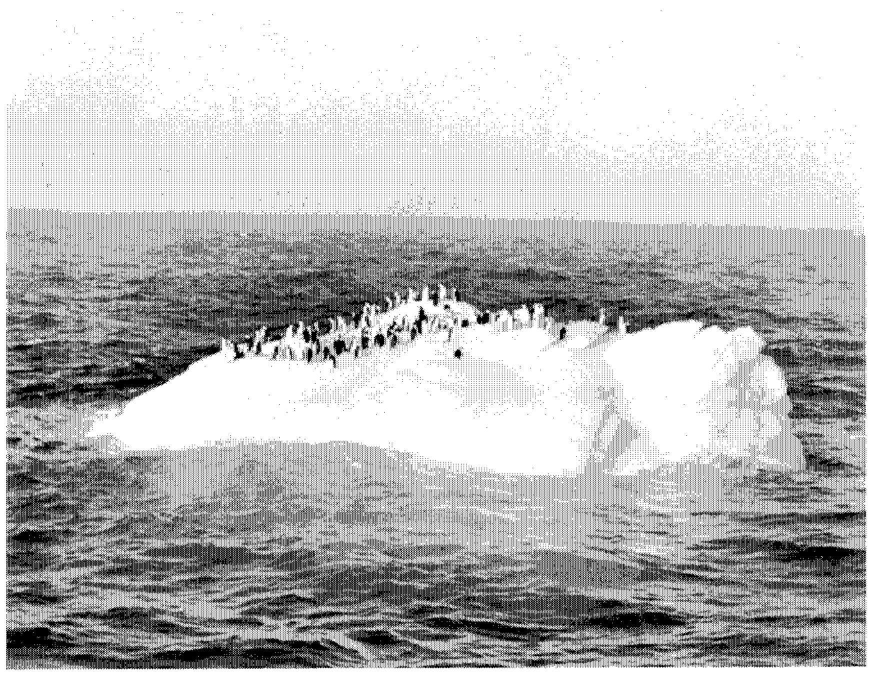
While the Joint Program with M.I.T. and the cooperative programs with other institutions are flourishing, it is becoming apparent that in one area of oceanography, biological oceanography, Woods Hole must provide all major components. The Institution has much greater talent in terms of research work on environmental problems than our sister institutions combined. We can continue to draw heavily on M.I.T., Harvard and other departments of biology for training in molecular biology, genetics and biochemistry. Ecology, population biology, systematic and evolutionary biology as well as the special aspects of life in the oceans are peculiarly associated with W.H.O.I. staff members.

Recent discussions with the Marine Biological Laboratory indicate the interest of that institution in developing year-round research programs in general ecology and related subjects. If these plans develop, Woods Hole will become an even more important center for the study of organisms as they live in the aquatic world.

H. Burr Steinbach
Dean of Graduate Studies

EDUCATIONAL PROGRAM ENROLLMENT
1972

	Number of Participants
Year-Round	
M.I.T./W.H.O.I. Joint Program Students:	
Resident at W.H.O.I.	31
Resident at M.I.T.	29
Woods Hole Degree Program	2
Postdoctoral Fellows	5
Marine Policy and Ocean Management Fellows	8
Other Graduate Students	3
TOTAL YEAR-ROUND	78
Summer	
M.I.T./W.H.O.I. Joint Program Students:	
Resident at W.H.O.I.	49
Resident at M.I.T.	9
Woods Hole Degree Program	2
Summer Student Fellows	17
Geophysical Fluid Dynamics Participants	7
Jake Hornor Traineeship	1
Other Graduate Students	2
TOTAL SUMMER	87



Penguins and bergs in Antarctic waters. AAW

Joint Woods Hole Oceanographic Institution-
Massachusetts Institute of Technology

DEGREE RECIPIENTS–1972

Doctor of Philosophy

CRAIG EMERY DORMAN
B.A., Dartmouth College, Geography
M.S., U.S. Naval Postgraduate School, Oceanography
Special Field: Physical Oceanography
Dissertation: *The Relationship Between Microscales and Wind-Wave Spectral Development*

ROBERT ALLIN FOLINSBEE
B.Sc., University of Alberta, Physics and Geology
M.S., Massachusetts Institute of Technology, Geophysics
Special Field: Marine Geophysics
Dissertation: *The Gravity Field and Plate Boundaries in Venezuela*

CHI-YUAN LEE
B.S.E., Cheng-Kung University, Civil Engineering
M.S., National Central University, Geophysics
Special Field: Physical Oceanography
Dissertation: *Long-Linear Internal Waves and Quasi-Steady Lee Waves*

CHRISTOPHER SLOCOMBE WELCH
B.S., Stanford University, Physics
Special Field: Physical Oceanography
Dissertation: *On the Calculation of Wind Stress Curl over Open Ocean Areas from Synoptic Meteorological Data with Application to Time Dependent Ocean Circulation*

Doctor of Science

TERRENCE MICHAEL JOYCE
B.S., Rose Polytechnic Institute, Physics
Special Field: Physical Oceanography
Dissertation: *Non-Linear Interaction among Standing Surface and Internal Gravity Waves*

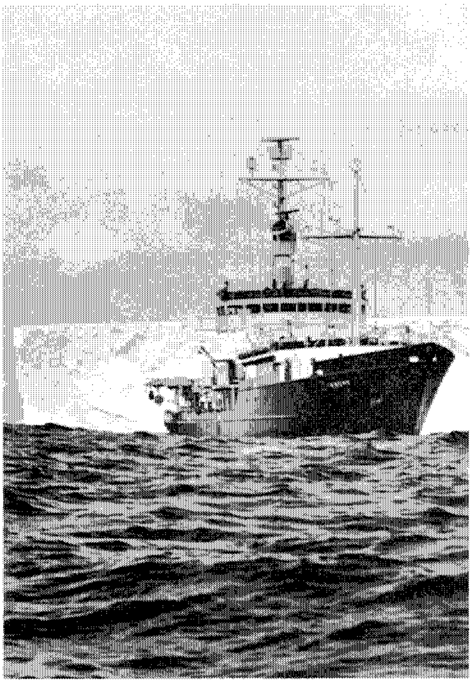
Ocean Engineer

JAY MARTIN COHEN
B.S., U.S. Naval Academy, Ocean Engineering
Dissertation: *An Experimental Analysis of the Dynamics of a Submerged Tethered Cradle in a Seaway*

RONALD CARL GULARTE
A.A., Hartnell College, Engineering
B.S.M.E. and M.S.M.E., University of Southern California, Mechanical Engineering
Dissertation: *Motion Sensitivity of Flame Ionization Detectors*

CARL STARCK ALBRO
B.S.M.E., University of Massachusetts, Materials Engineering
Dissertation: *Investigation into the Feasibility of Detecting Salt Fingers Optically*

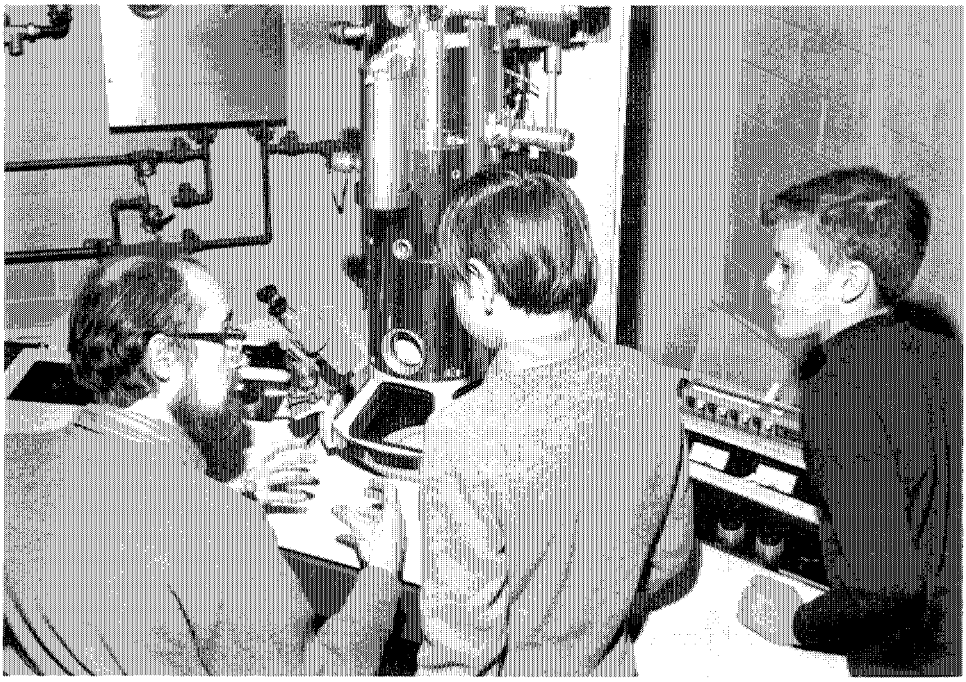
PETER FRANK PORANSKI
B.S., Newark College of Engineering, Engineering Sciences
Dissertation: *The Design of an Instrument to Measure Vertically Averaged Oceanic Currents Using Geomagnetic Electric Fields*



KNORR encountered ice in both Arctic and Antarctic waters.

Ushuaia, Terra del Fuego, a small village, 3218 kilometers SSW of Buenos Aires where KNORR spent Christmas.

Rounding Cape Horn.



Conceived by Carl Bowin, FOOS (Falmouth Out-of-School) gives sixth grade pupils an opportunity to learn about work in the adult world. Here Charles C. Remsen demonstrates the use and operation of an electron microscope.

Charles D. Hollister in the laboratory aboard Knorr.

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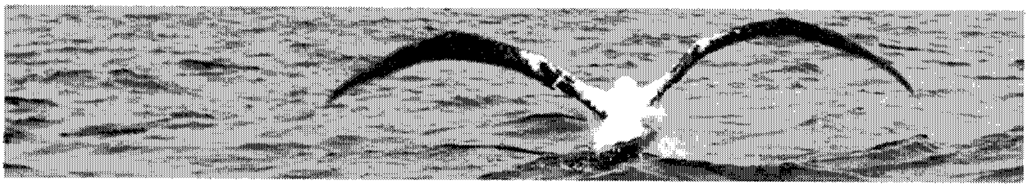

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Henyo T. Barretto
Petrobrás, Brazil
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Freshwater Institute, Winnipeg, Canada

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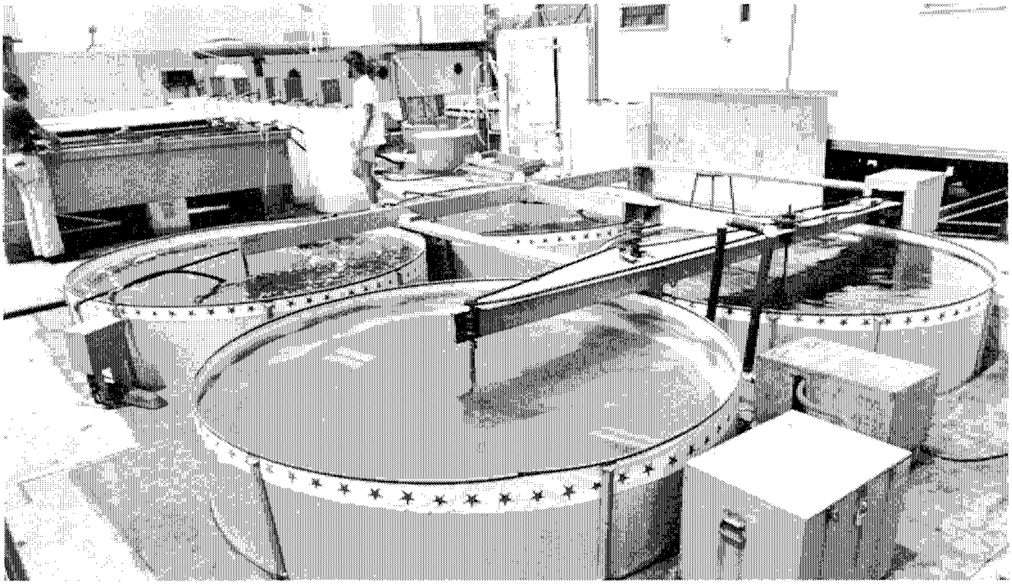


Algae cultured in pilot plant on dock in 600 gallon tanks (foreground) to feed shellfish in ten-foot-long tanks (rear).

Department of Biology*

There is nothing more interesting to report this year than the diverse experiments carried out from DSRV ALVIN at Bottom Station No. 1 on the continental slope south of Woods Hole in 1800 meters of water. Here, the submarine's ability to go deep combined with its manipulative skill lets us experiment in the deep sea in a way never before possible. These first experiments suggest that much of life on the deep ocean bottom, both animal and bacterial, proceeds at a much more leisurely pace than it does in benthic communities on the continental shelves. Some details are given below together with those for other parts of the department's work during 1972.

Microbiology

Specially-designed, pressure-tight, aluminum cylinders with racks of sample bottles were opened on the sea floor at Bottom Station No. 1 (1830 m) by ALVIN for inoculation and incubated there from June 1971 to June 1972. Rates of microbial degradation of agar, starch, and gelatin, with and without the addition of supplementary nutrients were one to more than two orders of magnitude slower than laboratory controls. Thus, the indigenous deep-sea microflora behaved similarly to bacterial populations of surface waters incubated under deep-sea conditions. From observations on animal and microbial attack of solid organic materials and from calculations of the amount of non-refractory organic materials reaching the ocean floor, activities of microorganisms in the deep-sea may be largely confined to the intestinal tracts of animals, where an enriched nutrient milieu permits decomposition of refractory materials (including chitin and cellulose) in an endosymbiotic fashion. The activity of marine psychrophilic bacteria at low temperatures and various hydrostatic pressures indicates that it decreases with depth in the oceanic environment.

*Completed papers are not cited in any of the departmental reports, but are listed among the publications, see pp. 65, or in subsequent lists.

Measurements of microbial activity made from enriched surface water (Eel Pond, Woods Hole) substantiated other data that the conversion of ^{14}C-labelled organic substrates at 40 m depth ("Buoy farm" off Cuttyhunk) was half that in the laboratory. This figure of 1:2 (activity *in situ* vs. activity in the laboratory at *in situ* temperature) contrasts with 1:200 in the deep-sea.

A pressure-retaining microbiological sampling and culturing chamber, already in use in the laboratory, will prevent decompression during retrieval of microorganisms from ocean depths for culture under unchanged conditions. It also allows the removal or injection of media without affecting the pressure within the chamber.

Colorless, marine sulfur bacteria (thiosulfate and sulfide-oxidizing) from offshore areas of the North Atlantic and the anoxic basins of the Black Sea and the Cariaco Trench differ from typical thiobacilli. The limiting step in the oxidative turnover of sulfur compounds in anoxic basins may be the biological oxidation of thiosulfate. It affects the growth rate and possibly the cell yield in organically supplemented seawater media. It was oxidized quantitatively to tetrathionate, independent of pH or the presence of organic compounds. In one strain this was dependent on the population density and the amount of thiosulfate provided. Some strains carry out the reduction of inorganic sulfur compounds other than sulfate at the expense of organic substrates. A Black Sea isolate reduced tetrathionate, thiosulfate, or sulfite when grown anaerobically in a mineral medium with lactate or pyruvate as the energy source. Microorganisms of this type may contribute markedly to the sulfur turnover by competing with *Desulfovibrio* sp. for partially reduced inorganic sulfur at oxygen/sulfide interfaces in anoxic marine waters or sediments.

Further determinations of photosynthetic productivity and a new approach to measuring methane oxidation were made in Lake Kivu during March and April. The rates of oxygen uptake and bacterial methane utilization in the zone of oxygen depletion provided data for calculating methane turnover.

Membrane studies were restricted to *Nitrobacter winogradskyi* which has peripheral cytomembranes studded with particles queued in rows. Membranes were isolated from other cellular components and were morphologically and biochemically characterized. The peptidoglycan layer of nitrifying bacteria, both marine and terrestrial, was isolated and chemically analyzed. While in most of these organisms it is similar to that in *Escherichia coli,* in two marine strains it differed chemically from other Gram-negative bacteria. Marine forms may have less peptidoglycan than terrestrial ones.

Marine photosynthetic purple and green sulfur bacteria have a variety of ultrastructural types. Chief among these are photosynthetic membranes which are present as flattened vesicles, chromatophores, tubes or chlorobium vesicles. Such diverse types permit testing membrane models including their functional and structural asymmetry in energetically active membranes. During photosynthesis, these bacteria require sulfide as a source of reducing power by oxidizing it to elemental sulfur. Some species deposit sulfur outside the cell, while others deposit it inside in membrane-bound globules. Where the sulfur is deposited appears to be directly related to the type of membrane system. In *Ectothiorhodospira mobilis,* the reducing power is limited by the concentration of sulfide in the medium flowing over the surface of the invaginated plasma membrane and sulfur is deposited outside the cell. In *Chromatium violascens,* where the chromatophores are formed by the invagination and subsequent pinching-off of the plasma membrane, sulfide may be trapped within the vesicle.

During CHAIN Cruise 105 many open ocean microorganisms were collected, tentatively identified, and preserved for electron microscopic examination. Bacterial and yeast cultures were also isolated. These are being examined for their sensitivity to polychlorobiphenyls (PCB) and DDT and for the cytological effects of sublethal concentrations of these pollutants.

Urea is present in biologically significant amounts in most natural waters: phytoplankton play a greater role in its utilization and/or decomposition in coastal waters, but in the open ocean the bacteria dominate. The rates of urea breakdown are much faster in coastal than in oceanic waters. Since urea cannot be utilized by all phytoplankton species, its presence may exert a considerable influence on phytoplankton species composition.

Plant Physiology, Ecology and Distribution

In the diatom *Thalassiosira pseudonana,* an estuarine clone had a higher half-saturation constant and maximum growth rate than one from the Sargasso Sea, but at certain times silicate concentrations in both areas may limit the growth-rate. In the nutrient-poor Sargasso Sea the silicate uptake is more efficient as is the case for nitrate.

Offshore isolates of phytoplankton species were significantly more sensitive to polychlorobiphenyls (PCB) than those inshore. Open ocean phytoplankton may thus be generally more vulnerable to abiotic environmental stress. In chemostat tests with natural plankton communities from Vineyard Sound 0.1 ppb of PCB, which is within the range of concentrations in the open ocean, was sufficient to inhibit the growth of *T. pseudonana.*

The fixation of atmospheric nitrogen by *Dichothrix fucicola,* an epiphyte of *Sargassum,* has been proven for the first time for a blue-green, heterocyst-bearing alga other than one in the genus *Oscillatoria* (*Trichodesmium*). The latter may double its nitrogen content, and thus divide, roughly every 47 days. These division rates suggest that much of the nitrogen required by *Oscillatoria* must be obtained by means other than nitrogen fixation.

Natural copper chelating agents protect certain diatoms from copper concentrations low enough to be of environmental significance. The diatoms themselves also produce extracellular chelators that coordinate with and detoxify copper.

An electrophoretic survey of enzymes from selected strains of marine diatoms may result in a workable system for determining species in taxonomically difficult groups. *Stichococcus cylindricus* Butcher previously thought to be a chlorophyte may be transferred to the newly formed class Eustigmatophyceae as seems indicated by the pigment content.

A tongue of cold water extending southeastward from the Grand Banks separated a southeastward flowing portion of the Gulf Stream from a northwestward flowing portion of a neighboring gyre. This hydrographic structure was a "sufficient condition" to cause a drastic discontinuity in the distribution of phytoplankton species in April and May. Two species groups — that in the cold tongue and that in the warm oceanic currents to either side — would not have occurred had it not been for the hydrographic discontinuity. It was also a "necessary" condition. In both groups all species varied in abundance with a minimum of interference from others in their group. Thus, the biomass was shared between species whose ranges overlapped considerably.

Although the floristic change is predictable at a marked hydrographic discontinuity the individual constituent species of the two groups are unpredictable. An abundant species in the cold tongue, a green, morphologically-changing euglenid usually seen in abundance only in shallow, enclosed bays, was most unpredictable. Minimal interference between species ought to increase the ease with which an unusual species can become abundant (i.e., unpredictability of occurrence) and with which species adapted to varying factors in the water types can become abundant (i.e., predictable change, in part). A necessary condition for the floristic change, minimal interference is also essential in the transformation of unpredictable species occurrences to a predictable floristic change.

The vertical distribution of the green alga *Halosphaera viridis* throughout the Mediterranean Sea at various seasons is curiously conspicuous in samples deeper than 1000 meters. These cells sinking at a rate of 8 to 33 meters per day may at times play an important role in energy flow to the deep benthos.

High-marsh grass production (*Spartina patens*) levelled off after three years due to the accumulation of nutrients in plants and soils. Differences in production between two levels of fertilization in the more frequently flooded low marshes (*Spartina alterniflora*) continued, though less marked than in the first two years. Losses of added nutrients in tidal waters remained low. Some seasonal variation in the grass standing crop may be accounted for by the effects of fertilization, light, and temperature on respiration and photosynthesis. Oxygen uptake by the benthic community is greater in fertilized plots. Nitrogen fixation has ceased in the plots in which fertilizers containing nitrogen have been added and denitrification was greater.

Animal ecology and distribution

Samples were collected in September at approximately 90 meters in the Sargasso Sea by a device towed from the surface, which was designed for use with ALVIN. Four transects were also made along the bottom at Bottom Station No. 1 (39°46′N, 70°41′W).

Techniques for differential staining of euphausiids and other crustaceans in the zooplankton at the time of molting have centered on a histochemical test to detect "phenoloxidase" activity which is thought to peak at ecdysis. A total of 30 plankton tows (with approximately 80 experimental treatments) were taken from the Sargasso and Mediterranean seas for such tests at sea. Although differential staining of individuals within several crustacean groups (amphipods, decapods, mysids, and possibly euphausiids) were significant it is still not known whether the technique is sufficiently sensitive to indicate *in situ* molting rates.

The phenotypic relationship of the species in the copepod family Candaciidae, was evaluated by factor analysis. Three factors accounted for 93% of the total variation among these and four clusters of species were recognized. The clusters agree with a phenogram based on correlation coefficients between species as well as with relationships among candaciids based on classical taxonomic considerations.

Of approximately 250 candaciid samples received from the Indian Ocean Biological Centre, 18 species in 150 samples have been identified and measured. These and others obtained by ATLANTIS II in the southern Indian Ocean, are sufficient for determining gross distribution, frequency, and abundance of candaciids in the Indian Ocean.

Plankton was collected in December 1971 from *Alvin* Bottom Station No. 1 in an area of calcareous sediment and low productivity. Not only was there a comparative paucity, but none of the copepod species taken off Woods Hole were caught there. The most common one at this locality was an undescribed calanoid copepod with the characteristics of two families, Augaptilidae and Heterorhabdidae.

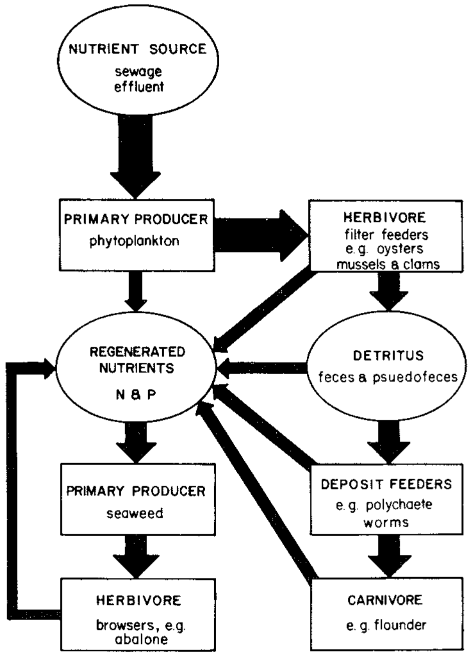
The entrainment of larval fish into the cooling water stream of the Millstone Point nuclear power station on northeastern Long Island Sound may harm local fish populations. About half the larval winter-flounder population in Niantic Bay (Connecticut) passed through the power plant. Few survived. About 80% of all copepods entering the plant never return to Long Island Sound. Although not immediately killed, they sink to the bottom of the effluent pond (ca. 30 m deep) and never pass over the shallow sill.

Hard polystyrene spherules, called "suspension beads" by the plastic industry, occur in coastal waters from western Long Island Sound to Vineyard Sound. These were also present in the gut of 8 to 14 fish species (270 individuals) and in a chaetognath, all from Niantic Bay.

During CHAIN Cruise 105 (June-July 1972) the salps, *Pegea confederata* and *Cyclosalpa pinnata,* were kept alive for six days. Continuous rather than intermittent feeding increased survival time. In the laboratory, they reproduced both sexually and asexually.

On a seven-week summer cruise between Newfoundland, Portugal, the Norwegian Sea, and Ireland (Chain Cruise 105), 146 midwater-trawl collections were made to complete the broad-scale sampling needed to describe the distribution patterns of mesopelagic fishes in the North Atlantic. Most of the fishes in the 119 eastern Atlantic tows (ATLANTIS II Cruise 59) and eighteen more from the Mediterranean Sea have now been identified. Of the Caribbean fish faunas, that of the Colombian Basin has twice the standing crop of the other two basins, but its fish fauna there is rather similar to the other two.

With 1,910 releases and 122 returns in 1972 the cumulative totals for the Cooperative Game Fish Tagging Program are 42,841 and 3,040, respectively. The return rates for



Flow diagram of tertiary sewage treatment — marine aquaculture system.

small bluefin again indicated heavy fishing pressure on the North Atlantic stock. The catch for bluefin tuna in tons per boat-day in the purse seine fishery continued its decline from a high of 18.2 in 1969 to about 5.0 in 1972. An almost complete lack of recruitment has resulted in serious declines or complete failure in all the northeast Atlantic fisheries for large bluefin tuna. Two small (about 10 pound) individuals released off southern New England in the summer of 1966 were recaptured. They weighed 264 and 350 pounds, considerably more than the 185 pounds predicted from growth studies. A double-tagging experiment was continued with the cooperation of the National Marine Fisheries Service and the Fisheries Research Board of Canada. Of the 119 returns, 40 had only one tag indicating considerable tag loss.

With two transects, one off Surinam and the other off Ireland, the field work was completed for the deep-sea benthic survey of the entire ocean floor of the Atlantic.

There are differing patterns of distribution for various deep-sea taxa. Those living in the relatively "chemostatic" and poor trophic regime of the deep-sea have a low reproductive potential and a high proportion of adults to juveniles in contrast to their counterparts in shallower depths. They may also be longer-lived, have lower metabolic rates, and be more sensitive to stress.

Thousands of square meters of the sea floor on the continental slope south of New England have been photographed from ALVIN for the larger epifaunal invertebrates and fish. Five species account for 97% of the animals counted. The faunal components change continuously in the depth interval between 495 and 1830 meters. Patterns of distribution for the most abundant species — aggregated, random, or overdispersed — were determined for bottom areas from 20 x 20 centimeters to more than 100 square meters. Four boxes of azoic (frozen and thawed) sediments were emplaced from ALVIN at the permanent bottom station in 1800 meters of water. These will serve as temporal markers in the seasonless deep sea to measure rates of colonization and growth by retrieving one box a year for comparison with similar experiments in the shallow waters of nearby Buzzards Bay.

The sampling phase of the West Falmouth oil spill study has now been completed, and the analyses of these samples are progressing well. Oil-related effects on the benthic biota that settled into the area were both evident and severe as much as a year after the spill. Following the oil spill, an opportunistic small worm (*Capitella capitata*) increased tremendously in number, then declined. Ten months later all individuals were monomorphic at the malate dehydrogenase loci, although heterozygous individuals occurred in unoiled areas at the same time. Three months after the spill there were individuals with two alleles and after two years with several alleles. Of the various genotypes settling from the plankton only one was favored by the oiled conditions. Thus the selection of one component of the total genetic variability in a local habitat may be the basis for adaptation in opportunistic species.

The larval stages and egg masses of many of the most common benthic prosobranch gastropods of the Woods Hole region are still unknown. Of forty-two species, the egg capsules of only twenty-seven can presently be identified and the mode of development has been determined for only thirty species (eighteen have phytoplanktotrophic larvae, twelve develop directly without a pelagic state). Of the eighteen species with planktotrophic veligers, only half the pelagic larvae have been described.

Preliminary analysis of the biomass of sixteen box cores taken on seven dives in Hudson Canyon with ALVIN between 200 and 1800 meters suggests that it is appreciably greater than in other areas. On two ten-day cruises on ALCOA SEAPROBE to Alvin Canyon and the continental slope along the Gay Head — Bermuda transect macrofaunal counts were made from 100 to almost 2000 meters in depth. There is no rigid faunal zonation with depth of fish in Alvin Canyon but each species seems to have its own depth preferences. In general, smaller specimens live shallower than larger specimens of the same species, but the converse is true for the witch flounder and the red crab, *Geryon quinquedens*.

A new genus and species of terebellid polychaete from the Tongue of the Ocean was captured by ALVIN. Animals were resting on and swimming above the steeply sloping walls of the trough. The worm's motility is perhaps a requirement for survival on an unstable substratum.

Forty-one samples of benthic invertebrates were taken from depths of 240-290 meters in the deep basins (Wilkinson-Murray) of the Gulf of Maine from ALVIN and GOSNOLD in the summers of 1971 and 1972. Their abundance and biomass were surprisingly low for depositional basins of so moderate a depth, possibly due to severe seasonal changes.

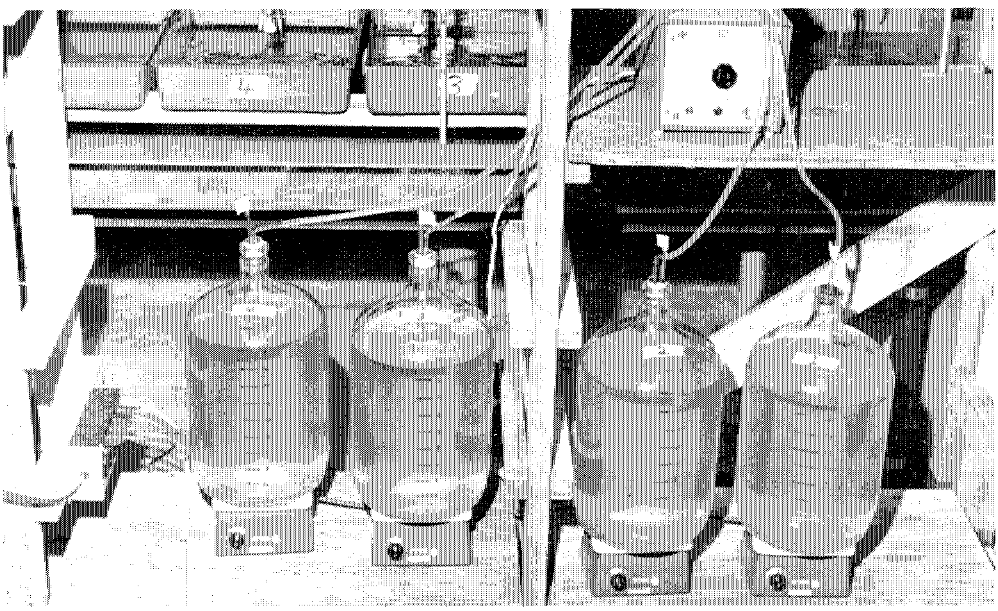
Thirteen box cores were taken by ALVIN at Bottom Station No. 1 (1800 m) to ascertain small-scale variations in animals and sediment. The current velocity necessary to erode these samples was about 100 cm/sec, but time-lapse films taken at the head of Hudson Canyon (300 m) indicate that biotic activity there causes erosion to begin at much lower velocities. The relationship of benthic fauna to the physical properties of sediments have been initiated in Buzzards Bay, preparatory to similar experiments from ALVIN in deep water.

Animal behavior and physiology

Sound sources were located and tracked to obtain information about both the animals and a non-rigid four-hydrophone array. Analysis of array data from Kealakekua Bay, Hawaii Island, gave information about the Hawaiian spinner porpoise that in most cases could not have been obtained with a conventional single hydrophone. Bursts of clicks were often answered within a half-second or less by another porpoise, no more than 10 meters distant and none were deeper than 15 m. Of three sound types, only the clicks had highly directional propagation characteristics. Intense low-frequency sounds from two minke whales had single downward sweeps in frequency from about 130 to 60 Hz, lasting about 0.3 sec.

A tracking radar taken to sea during the fall migration traced some 1200 birds. They were seen passing Bermuda going eastward again this year. Unfortunately, when ATLANTIS II was in proper position to observe where these birds were heading, the migration ceased due to unsuitable weather along the North American coast.

Swordfish have a thermogenic organ which appears to warm their brain. It may be useful in allowing the swordfish to remain active after a rapid temperature change on passing through the thermocline.



Algae cultured in the laboratory in bottles and fed to shellfish in trays.

There are certain similarities between this tissue and the brown fat which serves as a thermogenic organ in young mammals.

On a cruise between Newfoundland and Portugal, the horizontal and vertical distributions of the thecosomatous and gymnosomatous pteropods were related to temperature and pressure. The respiration of those caught in midwater trawls was measured under varying temperatures and pressures. The synergistic effects were pronounced and correlated well with the distributional patterns of the species.

The respiration of the *Sargassum* community was two to five times greater than for surface water plankton. In the slope water it was higher than in the Sargasso Sea, perhaps due to higher concentrations of nutrients and organic matter near shore. The community respiration was compartmentalized into epiphytic, macrofaunal, *Sargassum,* and microbial respiration: the latter was the most important.

Ingestion, egestion, growth, and respiration were measured in three size-classes of the Sargassum fish, *Histrio histrio* and compared to food availability in the Sargasso Sea. In small *Histrio* there was high growth but low respiration and assimilation. In larger fish the latter increased, but growth was reduced. There was fair agreement between the annual energy requirement for the fish and the food energy in the environment.

In mesopelagic animals, at pressures of 200 to 300 atmospheres, all experimental species (decapods, amphipods, mysids, and squids) went into convulsions and then became quiescent, although in some cases the heart continued to beat. Whether or not the animal died depended upon whether it was resistant to anoxia. The mysids and amphipods, which could survive in seawater bubbled with nitrogen for many minutes at surface pressure, survived under pressure. The decapods and cephalopods, which were not resistant to anoxia, were killed, presumably because their breathing movements were stopped at high pressures.

The major pathways of organic matter to the deep-sea floor are largely unknown, although potential ones include (a) sinking of large dead animals such as whales or macroscopic plants such as *Sargassum* (b) transport by turbidity currents, (c) transfer downward by "ladders" of vertically migrating animals, (d) convection and advection of dissolved organic matter and (e) sinking of small particles. The latter are of particular interest since they can sink rather rapidly, in some cases to great depths. A potential food source for deep-living animals, they may also convey surface-introduced organophilic pollutants (pesticides, PCBs, heavy metals) to the deep-sea. A prototype sediment trap for direct measurements of this falling material is ready for use just above the deep-sea floor.

The first *in situ* measurements of deep-sea benthic community respiration were made during the summer from ALVIN using bell-jar respirometers placed on the bottom at Bottom Station No. 1 (1800 m). Additional measurements were made nearby from ALCOA SEAPROBE. Oxygen uptake by these slope sediments and their fauna was two orders of magnitude less than for those on the shelf.

A small "reef" of six bales of compressed municipal refuse weighing about ten tons has been constructed in Great Harbor, Woods Hole, and two bales have been placed in deep water. At the former, within a few months a gas mixture including methane, hydrogen, carbon dioxide, and hydrogen sulfide began to evolve but there was no oxygen depletion in the cavities between bales. Substantial growths of filamentous bacteria, microscopic algae, barnacles, hydroids, and anemones on the bales have attracted starfish, gastropods, decapods and fishes.

The development of instruments for acoustic telemetry of biological data includes (a) a salinity/temperature profiler that provides a continuous plot of data to depths in excess of 400 meters (b) more efficient devices for telemetry of body temperature, water temperature, and heart beat used extensively on free-swimming fish in open water and in aquaria, (c) a small, simple, and accurate device for telemetry of depth, and (d) a reasonably simple and sophisticated receiver for acoustic signals.

Aquaculture

In the development of a combined tertiary sewage treatment-marine aquaculture system, the effluent from secondary sewage treatment, diluted with seawater, is used as a culture medium for the growth of unicellular algae (phytoplankton).

The latter are used as food for oysters, clams, mussels, or other filter-feeding bivalve molluscs. Solid organic wastes produced by the shellfish as feces and pseudofeces can be utilized by detritus-feeding invertebrates, such as polychaete worms or Crustacea, while secondarily-produced dissolved nutrients (ammonia, phosphate, etc.) can be eliminated by final passage of the effluent from the system through a seaweed culture. The seaweed can be grown for its intrinsic value or as a food for browsing invertebrates such as abalone.

Controlled laboratory studies were continued on the growth kinetics of mixed and single species cultures of marine phytoplankton reared on sewage effluents, and the effects of algal species, concentration, and flow rate on the feeding rate, organic deposition (feces and pseudofeces production), assimilation, and growth of oysters, hard clams, and mussels. A model of the complete system was also constructed and operated to determine the mass flow and utilization of nutrients in the various components and in the system as a whole.

Secondly, rates were determined for the uptake and loss of trace contaminants by the various components of the system, with emphasis on the shellfish. Preliminary measurements were made of the concentrations of heavy metals, PCBs, bacteria, and viruses in the sewage effluent, the phytoplankton grown on the effluent, and the oysters and clams which have fed upon the sewage-grown algae. Known concentrations of cadmium and PCBs were also added to the flowing system to determine the kinetics of uptake of these substances directly from the water (and from the algal food in the case of cadmium) by oysters and clams and the loss of these substances by the animals after the source had been removed.

Finally, a scaled version of the system was operated on the dock from June through October. For the first time an automated, fully-continuous flow system was successfully operated on a large scale in which new sewage effluent-seawater medium was added and the culture harvested on a continual basis at the rate of 50% of the culture volume per day. Thus the output of four algal-growth ponds was fed into four tanks with tray cultures of oysters, clams, and mussels. Output from these tanks was fed through similar tanks containing cultures of Irish moss, sea lettuce, and other seaweeds. A fifth tank containing all three shellfish received unfiltered seawater as the unfed control.

A new and promising technique is designed to separate, concentrate and measure a suite of heavy metals present in trace amounts in marine and fresh waters and accompanied by a high concentration of masking substances. The activated carbon approach employs two different but complementary physico-chemical phenomena, the adsorptive behavior of potentially useful chelons on an activated carbon matrix and the ability of adsorbed chelons to retain their ionic selectivity.

RICHARD H. BACKUS, *Chairman*

Chemotaxis experiments continue.

Department of Chemistry

The year 1972 signaled the beginning of the Geochemical Ocean Sections Study, the most ambitious project ever proposed to obtain detailed hydrographic and chemical measurements in the world's oceans. There are 19 institutions and universities participating, including scientists from Japan, India, Italy, France, Germany, Canada and the United States. In July the R/V KNORR departed from Woods Hole on the first leg of the GEOSECS Atlantic cruise. By December when she arrived at Ushuaia, Argentina, a total of eight thousand water samples had been taken for shore-based analyses and about fifty thousand chemical measurements completed at sea, in addition to continuous measurement on station of salinity, temperature, oxygen and light scattering. Operation of the program after years of planning has been almost flawless. There is no question that this project represents the coming of age for marine chemistry. The data collected will influence the concepts of oceanographers for decades to come.

Sea Water Chemistry

The GEOSECS Atlantic cruise completed 75 stations on a track from 75°N in the Greenland Sea through the western Atlantic Basins into the Scotia Sea between July and December of 1972. Shipboard measurements included salinity, temperature, oxygen, phosphate, nitrate, silicate, total carbon dioxide, partial pressure of carbon dioxide (PCO_2), dissolved nitrogen and argon, alkalinity, radon-222 on discrete samples, continuous measurements of conductivity, temperature, using the conductivity-temperature-depth sensor developed at the Institution and oxygen and light scattering using probes developed at the Scripps Institution of Oceanography. In addition to these analyses, samples were collected for shore-based measurements of trace elements, stable isotopes, particulates and the radioactive isotopes hydrogen-3, carbon-14, strontium-90, cesium-137, radium-228, and silicon-32. An important innovation of the shipboard program is the real time data acquisition system and the ability of the chief scientist to select sampling depths on the basis of real time information. Data on salinity, temperature, oxygen and light scattering are immediately available from the computer and are displayed on three oscilloscopes. A typical example of the detail being revealed by the measurements is the large increase in radon observed in the bottom 30 meters of the water column at most stations, due to diffusion of radon from the bottom sediments. Evaluation and interpretation of the data from these initial legs are now underway.

We have applied a vertical advection-diffusion model to describe the vertical profiles of total carbon dioxide, ammonia and phosphate in the Black Sea. A consumption of these three substances was calculated for the interval from 75 meters above the oxygen zero level to 175 meters below it. It is suggested that the observed consumption rates are due to the chemosynthetic fixation of carbon, nitrogen and phosphorus by chemautotrophic bacteria living at the oxygen-sulfide interface.

Temperature data from the Cariaco Trench, taken on cruises in 1954 and 1971, reveal that the deep water of the trench has warmed +0.07 °C over a 16-year period. If the trend continues, the deep water will become unstable in 150 to 200 years. In the deep water of the trench there is a maximum value of 26 micrograms of manganese per kilogram. Manganese accumulation probably began about 200 years ago and appears to be increasing at the rate of 100 milligrams per meter per year.

A technique for determining iodate to within ±0.5% in 50 milliliters of water has been developed. Iodate along profiles in the South Atlantic may be correlated with phosphate and nitrate. This indicates a surface depletion and a mid-water maximum coinciding with the oxygen minimum. Thus, iodate may also be involved in the biological cycles of the ocean. It is estimated that only 10% of the deep-water iodate is derived from oxidative decomposition of marine organisms and 90% is conservative.

For several years we have studied trace metals in sea water in order to understand their geochemical cycles, their chemical speciation, rates of transport, and behavior as tracers of oceanic circulation. Only certain elements could be determined because of the difficulty in making precise analyses at the low concentrations existing in sea water. Recently, a sensitive technique has been tried involving mass spectrometry of volatile metal chelates. The initial tests indicate that the elements chromium, nickel, copper and zinc can be determined at the one microgram-per-liter level in sea water mixtures containing other metals. A metal chelate-isotope dilution technique is also being used to measure sea water lead concentrations in order to estimate anthropogenic contributions to the lead cycle, and to examine deep-water scavenging and transport processes.

A method has been developed for determining chromium (III) and chromium (IV) with a sensitivity of 10^{-12} grams (picograms) chromium. Chromium (III) analyses have been completed for a vertical profile in the Sargasso Sea where the values were surprising high, ranging within 20% of the mean, 1.18 micrograms per liter. These high concentrations imply that the oxidation of chromium (III) which enters the ocean by weathering processes, is exceedingly slow relative to the estimated residence times of about 350 years.

Major element analysis of deep ocean samples by difference chromatography, do not vary significantly with depth or latitude in the magnesium/sodium and potassium/sodium ratios even though the detection limits for those ratios are 0.05% and 0.02% respectively. The only detectable cationic variation is that of calcium, which increases about 1% in deep water at mid-latitudes due to redissolution of calcium carbonate formed biologically at the ocean surface. Pore waters in marine sediments, however, have a sizeable variation in the proportions of all ionic constituents. These cation variations are now under investigation and new techniques for anion analysis are also being developed.

A new program has been initiated to determine the fate of sunlight in the upper layers of the sea. Questions being asked are: What are the primary absorbers of light in various types of sea water? How do they convert the energy they receive to other forms? What are the significant photochemical transformations other than photosynthesis? Organic pigments are concentrated from sea water, and an apparatus for irradiating samples with wave lengths in the solar spectral range has been designed and built.

Radiochemistry

Further examination of strontium-90 around the north and southeastern approaches to the Caribbean reveal that wherever a strong subsurface salinity maximum exists there is also one for strontium-90. The highest strontium-90 values, however, are often observed slightly below the highest for salinity. It is hoped that the source areas for this subsurface high-strontium-90 water will be discovered on a cruise to this region in the fall of 1973.

The ratios of strontium-90 to tritium and to carbon-14 are being studied in both the North and South Atlantic. In the latter, the strontium-90 to carbon-14 ratio diminishes by about a factor of two from 34°S, 17°W to 07°S, 21°W. Measurements of the strontium-90 to tritium ratio in the North Atlantic give an indication of the surface exposure of the water masses represented and these analyses are now being extended to the South Atlantic.

From estimates of the fraction of total plutonium delivered to the sea surface that has sunk to various depths in the water column, or has reached the sediment, it is concluded that plutonium associates with particles which have variable sinking rates. A curve which fits the data distribution in the Atlantic was made by assuming 30% sinking at 392 meters, 40% at 140 meters and 30% at 70 meters per year, but Mediterranean data both from water columns and from sediments did not fit this curve. In the Mediterranean much more of the plutonium still remains in the water and much less has reached the sediment. This tends to substantiate our original hypothesis that most plutonium sedimentation is biological, since it is known that the Atlantic is much more active biologically than the Mediterranean. The fraction of strontium-90 which has reached the sediments is not related to the depth of the overlying water. This indicates that it is due to particle fallout rather than to normal sedimentation processes. It appears that the distribution of cesium-137 in sediments and the overlying water column may also be used to estimate sinking rates for this nuclide.

During the past year a method was developed for the analysis of americium-241 and neptunium-237 in sediment, organisms and sea water. The same samples can also be analyzed for plutonium-239, -240 and -241 making possible several interesting isotope-ratio variations to use in delimiting various marine processes.

Less than 10% of the plutonium deposited from fallout in Lake Ontario was still in the water column in 1971, but the amount still in the water column had both horizontal and vertical gradients. Hence its residence time must be short compared with the mixing times. Plutonium in sediments along the southern border of the lake penetrated only a few centimeters, but in the deeper southeastern basin it occurred to a considerable depth in sediment cores. Sediment concentration in the deeper parts of the lake appears to be controlled partly by the bottom morphology and partly by sediment lithology and chemistry.

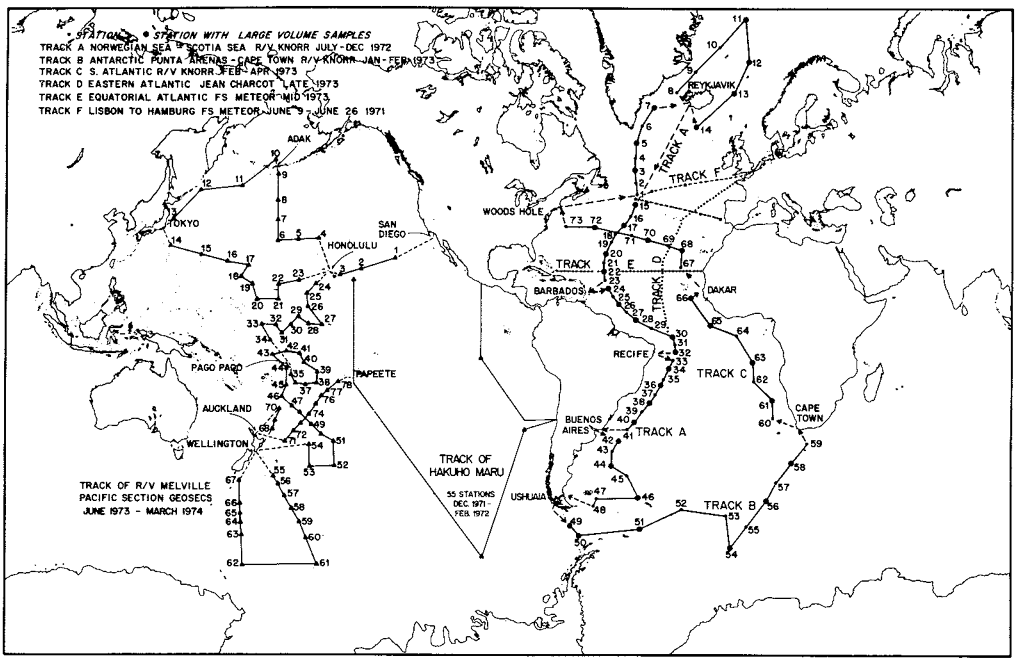
Geochemistry

King's Trough, a 200-mile-long deep depression (5000 meters deep) at 43°N, 22°W in the North Atlantic flanked by ridges rising above 2000 meters, was visited in the summer of 1972 as part of the continuing program on the geochemistry of the oceanic crust. Samples from a 30 to 60 million year old crust were obtained for comparison with the present ridge center.

From analyses of previous collections from various sites on the Mid-Atlantic Ridge the chemistry of the rocks penetrating transverse fractures appears to differ fundamentally from those originating in spreading centers. Rocks from "leaky" transform faults are more alkaline and are relatively enriched in sodium, potassium and such trace elements as barium, strontium, rubidium, and zirconium.

The submarine weathering of some Mid-Atlantic Ridge rocks yields potassium smectites, which are important traps for such ions as potassium+, lithium+, rubidium+, boron+++, and cesium+ from sea water. Chemical weathering of the glassy rind of pillow basalts results in oxidation of iron and enrichment in potassium+ and sodium+, accompanied by marked loss of calcium++, magnesium++, silicon++++, but chemical changes in the pillow interiors are much less marked. If these results exist elsewhere they may seriously alter current speculation on the role of rock weathering on sea water budgets which has been based only on analyses of weathered glass.

Basement rocks recovered during the JOIDES program at various distances from the Mid-Atlantic Ridge seem to have been similar in composition at the time of their eruption, despite intense weathering effects that have taken place over their age range of from eighteen to over sixty million years.



Geosecs cruise plan.

They were all originally tholeiitic basalts depleted of large ionic radius elements, such as potassium, barium, uranium and light rare earths. It appears that eruption of tholeiitic basalts similar to modern day eruptives at the Mid-Atlantic Ridge has been continuous since the beginning of seafloor spreading and that such rocks underlie much of the North and South Atlantic.

When heavy metal deposits were discovered in the rift valley of the Red Sea, it was predicted that similar deposits would probably be found associated with past and present hydrothermal emanations of the world's rift system. It now turns out that amorphous or poorly crystalline ferromanganese compounds and an iron-rich smectite (nontronite) comprise 10-20% and 70-80% respectively of the pelagic deposits in many parts of the East Pacific Rise. These deposits are enriched with copper, zinc, nickel and barium, with over half of the first two elements in the nontronite.

In determining the origin of the major ions in sea water, it is important to understand diffusive fluxes of these ions across the sea water-sediment interface. Recently a device was developed to obtain pore fluids from sediments *in situ,* which collects a profile of five filtered interstitial solution samples at 30-centimeter intervals from the upper 150 centimeters of sediment. Analysis of a series of eleven such profiles across the North Atlantic indicates that potassium has characteristically been depleted by two percent and that calcium has been enriched by four to six percent in the sediment pore waters. If similar gradients are observed over the world's oceans, the diffusive fluxes of potassium and calcium in response to these gradients would be comparable to the annual input of these cations by the rivers of the world. Long-term trends of diagenesis of the marine sediments of the world's oceans are being evaluated through a comparison of interstitial solutions in cores from the Deep Sea Drilling Project. In many biogenic sediments calcium^{2+} enrichment in pore fluid is accompanied by magnesium^{2+} depletion on a mole for mole basis. The absence of any alkalinity changes indicates that substitution of magnesium^{2+} for calcium^{2+} takes place in the carbonate. Strontium^{2+} enrichment up to 100 parts per million in the interstitial solution is also due to calcium carbonate recrystallization. In some biogenic sediments, sulfate (SO_4^{2-}) depletion also occurs with the loss of magnesium^{2+} exceeding the calcium^{2+} gain by an amount equal to the SO_4^{2-} loss. This may be explained by the precipitation of dolomite or the formation of an authigenic silicate such as chlorite.

Organic and Biochemistry

The isolation of the deep water of the Cariaco Trench from the Caribbean is responsible for the absence of dissolved oxygen below 300 m. Anoxic conditions are maintained by the balance between the supply of organic matter and the renewal of deep water. Recently δC^{13}* and total carbon dioxide values were used to determine the origin and oxidation of organic matter in the trench. It was calculated that about two-thirds of the organic carbon in the deep water of the trench was oxidized plankton carbon, with up to one-third due to the influx of continental organic matter. From estimates of the integrated accumulation of organic carbon in the water column and the oxidation rate, it appears that the renewal time of the deep water is about 100 years.

Early in 1972 a second expedition was made to Lake Kivu in order to complete the work on the African Rift Lakes. The lake contains about 50 cubic kilometers of methane, which is equivalent to the natural gas needs of the entire United States for about one month. The source of this meth-

** δC^{13} expressed in parts per thousand, is a measure of the difference in the C^{13}/C^{12} ratio between a sample and an arbitrary standard.*

ane has always been a puzzle. The residence time of the lake's deep water is about 350 years. All available evidence implies that the methane could not have been formed from plankton debris during such a short time, as had previously been assumed. Chemical and isotopic evidence argues against a diagenetic or volcanic origin. The bulk of the methane appears to be formed by bacteria utilizing volcanic carbon dioxide which enters the lake at several places, and volcanic hydrogen and hydrogen liberated during the formation of heavy metal sulfides which constitute a large part of the sediments. The energy liberated during the biosynthesis of methane may be partly responsible for increased temperatures in the deeper parts of the lake.

In ascertaining the fate and effects of oil spilled in the environment, it is important to distinguish between the indigenous hydrocarbons of organisms and sediments, and the hydrocarbons of fossil fuels. Thus analysis of a core taken in the polluted area of West Falmouth clearly exhibits the transition from purely petroleum-derived hydrocarbons at the surface to indigenous sedimentary hydrocarbons at some depth. The upper 2.5 centimeters of the core taken two years after the oil spill contains a partly degraded fuel oil whose carbon number range and compositional features are still to be correlated with that of the fuel oil. Between 2.5 and 7.5 centimeters both indigenous sedimentary hydrocarbons and fuel oil are easily recognized on gas chromatograms. The latter is less degraded than at the sediment-water interface. Below 7.5 cm there is no evidence for fuel oil hydrocarbons. The odd carbon predominance of the C^{17+} normal paraffins, a common feature of biogenic hydrocarbons, is apparent.

Continuing observation of the effects of oil off West Falmouth during the past three years indicate that there has been a gradual degradation of the oil by biochemical and physical processes. This degradation has resulted in a reduction in the immediate toxicity of the oil and a corresponding resettlement of the polluted region, first by the more resistant organisms and later by a more varied and normal fauna. Oil derived hydrocarbons still remain at all stations in the marsh and in Buzzards Bay. This indicates that the lifespan even of a low boiling oil in the sediments is to be measured in years.

Clear differences have thus been demonstrated between biogenic and petroleum-derived hydrocarbons in coastal areas such as West Falmouth, but the hydrocarbon geochemistry of sediments beyond the continental shelves is poorly understood. For open ocean waters and sediments no baseline data exist. In order to determine regional variability in sources and composition of hydrocarbons analyses have been initiated for sediments sampled on a transect from the New York Bight to the abyssal plain east of Bermuda. In addition, we are evaluating levels of biosynthesized and petroleum hydrocarbons in organisms on the continental shelf. Part of the work on hydrocarbons in sediments and organisms are concerned with the origin and distribution of the polycyclic aromatics which are far more common in petroleum than in unpolluted organisms.

Submarine oil seeps occur in some coastal regions; it is often intimated that organisms which have survived these natural seeps will also survive recent oil pollution. However, comparisons of known oil spillage with estimates of seepage indicate that the influx of oil from pollution exceeds that from seeps by several orders of magnitude. If seepage equaled the present oil influx from pollution it would have exhausted the total reserve of free-flowing offshore oil in less than 20,000 years.

An atlas of gas chromatograms has been prepared listing the composition of open ocean tar balls. The data are descriptive of the origin of the tar balls: crude oils, products, blends, and tanker washings, and of the ageing processes such as evaporation, dissolution and microbial degradation.

The problem of identifying unknown oil spills at sea is particularly complex considering the hundreds of tankers that pass along our coastlines. Last year we designed and tested exhaustively a simple, yet highly specific method of correlating unknown oils with their sources. From analyses of a series of artificially weathered oils by this technique, some 80% could be correlated with their source oils. Correlations were independent of the length of exposure up to 30 days, or the presence of spill-control chemicals other than oil-based formulations. The only indefinite results involved two very similar source oils that had already been highly degraded in sub-surface reservoirs. The method is now in use by several laboratories and is being considered seriously by several agencies with responsibility for water quality management.

The survey of the distribution of industrial chlorinated hydrocarbons such as DDT and the polychlorobiphenyls (PCBs) in the Atlantic Ocean has been expanded to include water and air sampling. Surface waters of the North Atlantic contain about 20,000 tons of PCBs, but less than 1,000 tons of DDT. The PCBs were even detectable at depths of 3,000 meters. Surface concentrations were the same from areas out to the open sea, indicating the importance of their transport in the atmosphere. Mixed plankton in the North Atlantic contained relatively constant levels of PCBs, around 100 to 500 parts per billion. Mesopelagic organisms which feed at the surface at night and migrate downward during the day are probably responsible for transporting tons of chlorinated hydrocarbons from the productive zone into the deep sea. DDT and PCB concentrations in these species of fish and Crustacea are related to the quantity and kind of lipid in each species. More than 90% of the chlorinated hydrocarbons in the atmosphere appear to be in the vapor phase and not associated with the dust. Consequently, the major pathway into the ocean must be by washout during precipitation, rather than as fallout on particulate matter. Low PCB concentrations in the plankton and water of the Sargasso Sea is probably due to the low annual precipitation there.

A new project has been initiated to investigate the responses of open ocean microorganisms to chemical pollutants such as DDT and polychlorobiphenyls. Initially these are being determined for marine bacteria, phytoplankton, algae, and Acantharia. In the course of this work it was discovered that Acantharia are frequent and often abundant in plankton tows taken just off Gay Head. They were previously unnoticed because of complete dissolution due to the preservatives used.

We have been examining the chemistry of the molting hormones of the female lobster to determine if it is in anyway related to her sex pheromone. Compounds with molting hormone activity such as β-ecdysone, inokosterone, ponasterone A, and cysterone were tested for their capacity to elicit sexual responses in the male lobster. No response occurred, indicating that these hormones are not the sex pheromones. The metabolic products of the ecdysones also had no sex attractant response.

Several of the lobsters appeared to be suffering from a molting hormone deficiency. Since they did not molt very well, the new shell did not harden properly. Apparently the diet may have a considerable effect on hormone production. Since the general feeding habits of lobsters in their natural habitat are poorly known, the nutrition must be determined both for immature and for adult lobsters in order to

Open house at the Geosecs building.

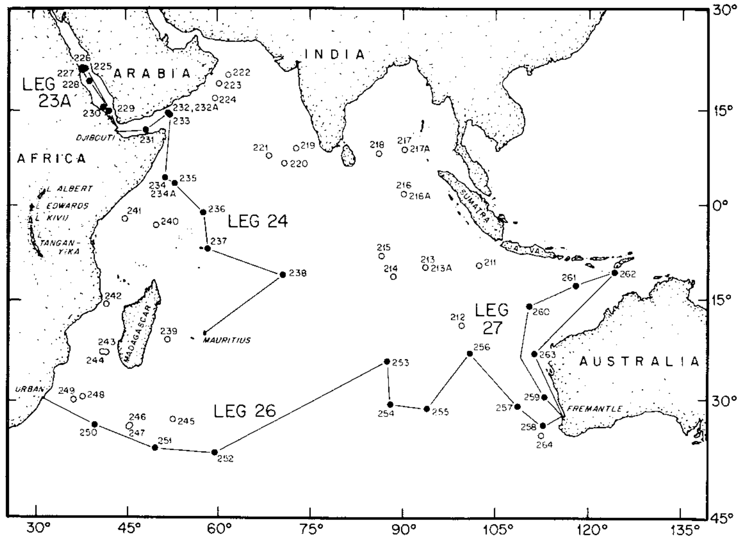
assess their need for certain basic foods for molting survival, fertility and growth.

It has been theorized that catfishes and possibly other aquatic animals use their chemical senses for distinctly different purposes — taste for localizing and testing of food, and smell for such social behavior as species, sex, individual and status recognition, and home range recognition. Recently, in a cooperative investigation with Texas A & M University, we explored the taste and sense of smell in catfish by surgical elimination of these centers in the brain. Preliminary results indicate that the sense of smell serves as a stimulant of activity. Even simple nose plugs may slow down their swimming. Taste removal, however, has no such slowing effect.

During the past year the first set of experiments were completed on the effects of sublethal, thermal and oil stresses on the behavior of fishes from the same ecosystem at different levels of social organization. The schooling species was represented by the golden shiner, *Notemigonus crysoleucas,* the territorial and hierarchial species by the sunfish, *Lepomis gibbosus,* and a socially complex and diverse species by the yellow bullhead, *Ictalurus natalis.* With increasing levels of social organization there was a substantial increase in communicative behavior, from 24 elements of behavior involved in the golden shiner to 98 in the yellow bullhead. Sublethal stresses induced by high temperatures and exposure to water soluble fractions of crude oils markedly influenced the behavior of the yellow bullhead well below the levels at which they died. The territorial species was less influenced by these sublethal stresses, and the schooling species was the least affected. Thus, the lowest level of fishes seemed best equipped to survive sublethal stresses.

The behavior of lobsters through the first eight stages of growth may reveal the biological basis of cannibalism and aggression in this commercially valuable species. A behavioral dossier has been completed for all eight stages: social organization increased at each stage, with hierarchical relations playing a dominant role in regulating the communities by the eighth stage.

JOHN M. HUNT, *Chairman*



Sites drilled by GLOMAR CHALLENGER in the Indian Ocean. Lines show legs on which the Chief Scientist was from Woods Hole.

Department of Geology and Geophysics

Noteworthy field operations during the year included four legs on the GLOMAR CHALLENGER drilling ship in the Indian Ocean, six months' surveying the West African continental margin on ATLANTIS II, initiation of similar operations on the continental margin of Brazil and numerous cruises of shorter duration by ships and submersibles in various oceans, as well as other special work on the rift lakes of Africa.

Drilling and other activities in the Indian Ocean

On each of Legs 23A, 24, 26 and 27 of the GLOMAR CHALLENGER one of the Co-chief Scientists was from the Department of Geology and Geophysics. These legs constitute more than half of those in the Indian Ocean and included personnel that were also on the CHAIN in the Indian Ocean last year. Placement of the sites, the tectonic and structural framework for them and the problems to be addressed by the Project's specific capabilities were derived from the geological-geophysical achievements of the International Indian Ocean Expedition, a cooperative exploration by many ships, scientists and agencies in numerous countries during the 1960's. The Institution had co-operated in these major objectives during that period. Leg 23A began in and returned to Djibouti French Territory of the Afars and the Issas, with specialists on the Red Sea on board. Six holes were drilled: one of the more interesting ones reached a salt layer which appears, from seismic profiler records, to be exposed at the level of the hot brines in the axis of the Red Sea. Leg 24 traversed 4500 nautical miles from Djibouti to Mauritius and drilled at eight sites and Leg 26 began at Durban and terminated at Fremantle after sailing 5530 miles and drilling nine sites. Basement as old as Late Cretaceous was obtained in the southwest Indian Ocean; the Ninetyeast Ridge appears to get younger toward the south; Broken Ridge is at least Santonian/ Campanian (80 million years) in age and Naturaliste Plateau older than 105 million years. Leg 27 sailed north from Fremantle to within sight of the island of Timor, then returned to Fremantle. Five sites were drilled: basaltic basement was reached at three of them, but drilling was stopped for mechanical reasons on a fourth within a few meters of basement. The oldest part of the Indian Ocean was discovered in the Argo Abyssal Plain (Site 26) with sediments from Early Cretaceous/Late Jurassic (140 million years) in age.

The CHAIN observations from the Red Sea indicate that its early history can be correlated with that of the Mediterranean to which it was connected in the Miocene at a time when it was isolated from the Indian Ocean. Based on analyses which have now been completed, the magnetic anomalies point to a crustal spreading at a rate of 1.6 cm/yr and bottom photographs reveal numerous volcanic and sedimentary structures, not unlike those in the rift valleys of mid-ocean ridges and surprisingly mound-building organisms near the hot brine pools.

The 1971 data from Ninetyeast Ridge indicates that it consists of en-echelon, north-south trending topographic structures. A fracture zone trending north-south parallel to the overall trend exists along the edge of this topography. It probably marks the principal site of dislocation between the central Indian Ocean and Wharton Basin plates. The Ridge is inferred, from gravity anomalies, to have originated from emplacement of gabbro and serpentinized peridotite under normal oceanic crustal layers.

Special note was made of records taken in the northwest Indian Ocean on and near Chain Ridge and its buried extension continue southward toward the African coast. The ocean floor to the west of this ridge may be at least 30 million years older than that to the east. This age difference is not inconsistent with deductions concerning continental drift and other data obtained aboard the GLOMAR CHALLENGER.

In March multidisciplinary surveys were made on lakes Kivu, Edwards and Albert, as part of a continuing investigation of all the rift lakes of Africa. The program includes hydrologic, geochemical, biological, geological and geophysical elements.

Cruises in the Pacific

The results of the 1971 CHAIN cruise in the Java Sea have been analyzed and combined with earlier observations of the Singapore Platform and the Sunda Shelf basin area. Tectonic units have been distinguished and these, with ages from geologic land formations, have permitted the development of a scheme of continental evolution. Aboard the HAKUHO MARU as part of a United States-Japan cooperative program an extinct spreading center was located in the western Philippine Sea at the site of what had previously been thought to be a major fault zone. This provided another important clue in the continental reconstruction of marginal seas of southeast Asia.

The size distribution and particle type sediments suspended in the waters of the Asian marginal seas (East China Sea, Yellow Sea, Sunda Shelf and Java Sea) were determined for about 1000 filter samples. Coccolithophorids from the filtered material were also examined for comparison with those in other environments.

Over ninety species of coccolithophorids were enumerated in water samples collected previously in the Pacific along the 155°W meridian from 50°N to 15°S, from the surface and at various levels down to 200 m depth. Insofar as possible these were correlated with the water masses of the western Pacific.

Geophysical data taken on the CHAIN 100 cruise to the Woodlark Basin in the Solomon Sea and the New Hebrides Island Arc reveal a spreading center in the Woodlark Basin and the heat flow measurements appear to correlate with anomalies of earthquake wave transmission. The rocks of Mitre Island indicate that it is unrelated to the New Hebrides Island Arc. The oldest known volcanic rocks from the latter are petrographically and geochemically distinct from those of the Tonga-Kermadec Arc. Hence these were probably never structurally continuous as has sometimes been intimated.

Antarctic Bottom Water proceeds northward in the Pacific mainly through a passage paved with manganese nodules near Samoa, where there was severe erosion during the late Tertiary. A bathymetric, current, and temperature survey was completed to determine the total flow of water there at the present time. Examination of the bottom sediments should unravel the depositional history in this passage during the Cenozoic.

One of the most intensely productive areas in the world's oceans, is located in the upwelling areas of Peru. Beneath this, there is a band of phosphate-rich sediments, which are chiefly diatomaceous organic-rich muds, but which also contain a complete sequence of phosphatized Holocene Foraminifera. There are no rock fragments or other evidence of reworking, dissolution, or recementation of pre-existing phosphorite deposits.

On Legs 7 and 8 of the Scripps Institution of Oceanography, South Tow Expedition over the Galapagos Ridge approximately 140 heat flow measurements were made during a joint expedition. Values ranged from near zero to as high as 30 heat flow units with smooth variations over a wave-length of several kilometers. Additional determinations were made over a long profile across the East Pacific Rise from Callao, Peru, to Tahiti.

Atlantic Cruises

As part of the nearshore phase of the International Decade of Ocean Exploration, a major survey of geologic and geophysical features of the continental margin of Brazil was begun. During the first year of a cooperative program with PETROBAS of Brazil, a review was made of existing data on the morphology, sediments, structure and oceanography in the area. A cruise of 4500 miles was likewise completed in November and December over the southern margin of Brazil, where two major sedimentary basins were located.

North of Puerto Rico the flow of Antarctic Bottom Water was traced through Vema Gap, across the Hatteras Abyssal Plain, and along the continental rise to the Greater Antilles Outer Ridge. A contour-following current flows around this deep submarine feature with current speeds of up to 80 centimeters per second. There may be as much as 6.5 micrograms per liter of suspended matter in these waters. It would presumably be deposited in areas of shear between opposing currents. Thus, the distribution of sediments on the seafloor at present, and in the geologic past, may be interpreted in terms of the flow of the bottom water.

Areas of sediment erosion and deposition were located in Hudson Canyon from a submersible and surface vessel and related to current movements. Sediments are being eroded from the northeast wall due to the activity of benthic organisms and are being deposited on the south and west walls. Strong tidal currents and turbulence phenomena, such as eddies, were also observed, but there is no evidence of turbidity currents. On the lower reaches of the east wall are bare rocky cliffs which overhang in some areas.

On a cruise of ATLANTIS II over the continental slope south of Martha's Vineyard in the general area of the ALVIN bottom station, gullies and larger features including Alvin Canyon were noted oriented normal to the slope. A scarp forty miles long was

Francis P. Shepard and his wife Elizabeth on ATLANTIS II off the west coast of Africa.

mapped. In the lower continental rise hill area to the south, linear features parallel the slope of the continental rise and are probably related to faulting.

In the Gulf of Maine, seismic reflection, magnetic profiles and sonobuoy refraction records delineated northwest trending faults in the western part of the Gulf. Sediment analyses and carbon-14 dates on cores have depicted the history of sedimentation since the last glacial advance about 18,900 years ago. Two cores were obtained in the Gulf of Maine by the "giant corer": one in Stellwagen Basin was 33.5 meters long and the other from about three kilometers to the east was 19.7 meters. Mechanical properties of these cores have been related to reflectors noted on the 3.5 kHz depth sounder.

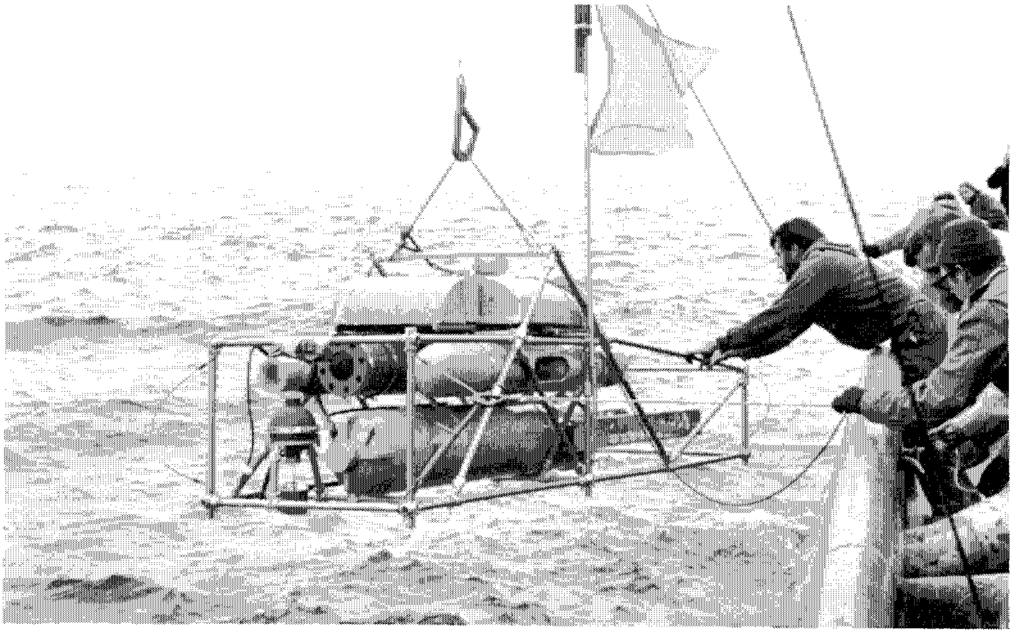
The first part of an aeromagnetic survey in collaboration with the Naval Research Laboratory was completed in the Greenland Sea and Arctic Ocean between latitudes of 76°N and 83°N. The axis of the Mid-Atlantic Ridge crest can be inferred beneath the ice cover. It appears to be made up of numerous short en-echelon spreading axes offset by transform faults along the Atka Ridge between 78° and 82°N. Another major anomaly was located along the eastern Greenland continental shelf break, which had been poorly known due to the permanent ice cover.

During November and December the ATLANTIS II examined a portion of the axis of the Mid-Atlantic Ridge south of the Azores, where the ALVIN and two French submersibles will dive for geological work in 1974. Activities have included dredging, underwater photography, recording the intensity and frequency of microearthquakes on the sea surface by sonobuoys, magnetic and wide and narrow beam bathymetric surveys all with navigation techniques accurate to within a few tens to a few hundreds of meters. Early in the year magnetic, seismic and narrow beam echo-sounding surveys were made over the Oceanographer Fracture Zone from the U.S.N.S. HAYES in cooperation with the Naval Research Laboratory. Much more remains to be done.

Quaternary sediments on the northwest African continental rise utilizing existing cores from several institutions were compared using the clay mineral assemblages on the African and the better known eastern North American continental rises.

A systematic exploration was made of the eastern Atlantic continental margin from Cape Francis, South Africa, to Luanda, Angola in early 1972. During seven cruise legs twenty geophysical profiles extended across the continental shelf to the mid-continental rise and five others continued to the Mid-Atlantic Ridge. Surface water parameters were measured while the ship was underway. Two fracture zones were investigated for azimuth and displacement, several new seamounts were found, a large submerged ancient delta of the Orange River was mapped, a belt of diapirs off Angola was delimited and the topography and other characteristics of the Congo Submarine Canyon were detailed. Participating were representatives from eight other nations. Provision has been made to transmit charts and profiles as soon as possible to the adjacent African countries and other interested organizations.

JAMES R. HEINTZLER, *Chairman*



Recovery of the Autoprobe, Optical Salt Finger Detector, CTD package from the R/V CHAIN, *December 1972.*

Department of Ocean Engineering

Deep Submergence Engineering and Operations

The Deep Submergence Program entered its second decade in 1972 with DSRV ALVIN in the Iselin Building high-bay area for the first time, undergoing an annual inspection and maintenance period following the 1971 operating season and also modification for the new hull. The engineering staff was fully occupied by a variety of developmental tasks, as well as in the direct engineering support of the ALVIN refit and LULU's preparation for departure for Florida early in 1973 to serve as the principal support ship for the Florida Aquanauts Research Expedition (FLARE).

The operational period (mid-May-October) began with shallow water trials in the harbor, ending with the deep certification dive by the end of May. Eleven more cruises were then conducted to carry out various scientific and engineering experiments. Dive locations, 77 in all, extended from the northern Gulf of Maine to the deeper end of Hudson Canyon. The limitations of funds and the delay in the original schedule for the new titanium hull, prevented deployment to southern waters during the fall and winter of 1972.

The titanium hull expected in Woods Hole by mid-March 1973 will double the operating depth of ALVIN and will provide for a greater payload. There will also be more available electrical connections through the hull. One of the major systems, the variable ballast, required for deeper dives was installed in the spring of 1972 and worked successfully throughout the operating season. The Naval Ship Research and Development Center, Annapolis, Maryland, designed, built and tested this system and assisted with its installation and engineering during the trial period.

Three major projects, FLARE, Underwater Acoustic Navigation and SCAMP (Self Contained Auxiliary Modular Platform) were primarily carried out by the Deep Submergence Group. In addition, support engineering for principal investigators in other departments, or activities have been provided. This included a deep pressure retaining chamber, a wide mouth specimen sampler, a sediment trap, a self-contained rock drill, and a hard rock chipper.

Information Processing and Analysis

Computer usage both ashore and on shipboard increased markedly during the year. There is a growing emphasis on computer analysis involving programs for the Sigma 7 at the processing center and for the Hewlett-Packard systems, either on shipboard or in the laboratory. As an example the data acquired from the ACODAC (Acoustic Data Capsule) field programs undergoes a preliminary analysis on the Hewlett Packard, one third octave or narow band, which is digitized, and the editing, final processing, and plotting is then completed on the Sigma 7/PDP-5. The Information Processing Center continues to (1) provide technical services to the Institution's computer users, (2) operate, maintain, and develop software for the general purpose Sigma 7, (3) operate and maintain the shipboard computer systems and satellite navigation systems, and (4) develop and operate computerized aspects of the Institution's business-work. During 1972 an education program was started with responsibility for teaching statistics and related subjects as part of the joint Massachusetts Institute of Technology-Woods Hole Oceanographic Institution program.

The Sigma 7 has served the Institution for nearly five years and all aspects of its operation continue to improve. During 1972 two major changes were made: first, 16,000 words of core memory were added bringing the total core to 48,000 words and secondly, the basic operating system was changed from a serial mode (one job at a time) to one which allows simultaneous computing and input-output operations. In late December 1972, a dual spindle disk pack system with an one-line capacity of 50 million bytes was delivered for installation in early 1973.

A shore-based Hewlett-Packard 2100 computer was installed in the DESC building. Peripherals were also added to the three shipboard systems to bring each up to equal computing levels and to increase the overall through put rate of each system. The cruise for the International Decade of Ocean Exploration on the R/V ATLANTIS II had an installation of four computer systems for the various scientific experiments. The basic Information Processing Center shipboard computer system still remains the central computing facility to accommodate the various tasks of scientific processing, while the other project systems meet the need for specialized instrumentation systems. The tendency to supplement the central computer system with additional project-oriented computers is increasing. Two additional systems, one for acoustics, and the other for physical oceanography, will become fully operational within the next few months.

Instrument Engineering

Unlike commercial instrument development where the eventual customer is somewhat removed from the designer and developer, here the customer is part of the organization, and is often deeply immersed in the design, development and "debugging".

The vector averaging current meter, the electromagnetic current meter (Sanford), and a solid state magnetometer are examples of instruments that have been improved or developed during this year in close cooperation with the user.

Sofar Floats

The large Swallow floats (5 meters long), that are tracked acoustically from shoreside listening stations, and that record temperature, pressure, and vertical velocities were field-tested during September and November on cruises of CHAIN. Results have been most satisfying, with strong signals being received hundreds of miles away, and with the internal recordings also working well. A production schedule was set up for the number of units required in the MODE experiment and construction is proceeding.

Salt Fingers

Salt fingers, with a scale of centimeters, are a feature of the interface between a warm, salty layer and a lower cooler, fresher layer. This form of microstructure consists of downward moving fingers of salty water, which lose heat faster than salt, interpenetrated by upward moving fingers of fresher water, which gain heat faster than salt.

A search for such fingering interfaces in the ocean was rewarded in September by photographs of columnar microstructure in the thermocline from 150 to 400 meters just south of Puerto Rico while working on board R.V. CRAWFORD. These photographs were associated with large gradients for temperature and salinity. The instruments used in the search for salt fingers, which were developed or adapted to the task, were mounted on Autoprobe. An optical instrument sensitive to inhomogenieties in the index of refraction of sea water was constructed to take horizontal photographs of the adjacent five-centimeter sections of the water column. A number of cases can be distinguished with this instrument. Uniformly exposed photographs indicate homogeneous water. Vertically banded photographs indicate salt fingers. Photographs with randomly oriented wavy lines indicate active mixing of water which is not homogeneous. Extreme inhomogenieties produce a pattern of small cells of high contrast. Coding on the salt finger photographs allows precise correlations to be made with the microstructure salinity-temperature-depth profiles recorded on tape. Each type of optical pattern can be associated with a characteristic profile of salinity and temperature.

On CHAIN Cruise 109 similar observations were made off the continental slope with Autoprobe sinking at a uniform rate of 7 cm/sec and obtained an excellent measurement of microstructure and salt fingers.

Autoprobe

Autoprobe, a general purpose autonomous observational platform, has the capability of making various programmed changes in depth much like an unmanned submarine. It can change its displacement in response to internal commands as desired. Acoustic telemetry is utilized in the instrument resulting in navigational information as well as temperature and pressure data. In addition there is an Acoustic Command System that can be used for various desired functions such as jettisoning weight, surface remote control operation, or changing program functions.

Autoprobe was utilized during 1972 for a total of thirty-one dives as an operational instrument in field observations. For North Atlantic circulation studies as an isotherm follower, a series of eight dives was made with the longest being 18 hours. Although mechanical and pneumatic difficulties interfered with its performance as an isotherm follower, it tracked a water mass on several dives, recording water temperature and pressure. Since then the pneumatic and mechanical problems have been solved.

Microstructure Salinity-Temperature-Depth System

The temperature and salinity structure of the oceans may have small step-like changes which must be measured with great resolution. Over the past two years a microstruc-

ALVIN during normal submergence.

ture STD system (Salinity, Temperature, Depth) has been developed at the Institution: it consists of an underwater unit which measures conductivity, temperature, and pressure, and a deck unit to process signals from the underwater unit. These three parameters are sensed, digitized and transmitted from the underwater unit in the form of 16 bit words, 30 times per second, via a cable to the deck unit which provides the following: serial or parallel output to a computer, digital display in engineering units, digital display of computed parameters — e.g. salinity, density, and analog outputs. The deck unit is thus an inexpensive but powerful interface unit between the underwater unit, computer, graphic plotter, etc.

The original system was first tested at sea during February 1971 and since then has undergone eight additional sea trials. The equipment performed well during these trials and considerable interest in the system was aroused. Consequently, the main effort this year has been design simplification in an effort to simplify assembly, check out, calibration, shipboard operation and adaptation to a variety of applications and configurations.

The sensor and digitizer circuits of the underwater unit were redesigned with these results: the circuit cards reduced from 23 to 16, power consumption was reduced from 1 watt to 0.4 watt, noise in temperature circuits reduced by a factor of 8, and noise in pressure circuit reduced by a factor of 4.

A new technique for very accurate, very high speed temperature measurement was evolved. This technique utilizes a high speed thermistor (25 milliseconds) and a precision platinum thermometer (300 milliseconds) and special circuitry such that the output has the excellent stability of the platinum thermometer and the fast response of the thermistor and is not affected by slow changes in the calibration of the thermistor.

The deck unit containing the demodulator, decoder and display (analog and digital) modules has excellent tolerance to noise, parallel as well as serial outputs to permit interfacing with computers such as the IBM 1800, and the ability to display and plot computer generated and raw data.

At present there are eight systems in existence and there will be more in the future. Of these, the original unit was first tested in February 1971, a second unit presently is in use by the Buoy Group, Numbers 3, 4, 5, 6, and 7 are being used by the Operations Group of the GEOSECS (Geochemical Ocean Sections) Program. The eighth unit was used for salt finger investigations and was mounted on Autoprobe along with special optical equipment. Consequently, the work involved in "streamlining" the design has already proven to be very worthwhile.

ACODAC Program

The Acoustic Data Capsule (ACODAC) is an unattended instrument package for collecting acoustic data for extended periods of time throughout the deep ocean water column. The outputs from six hydrophones in a vertical array are recorded according to preset instructions which depend on the mission. Gain settings, calibrations, and time are automatically recorded. Acoustic telemetry permits checking on the instruments *in situ*, navigation and recall for recovery. The first two ACODAC systems were designed and constructed at Woods Hole in 1971 and were improved before field trips in 1972: in June and October near Bermuda, near Madeira in August, in the Ionian Sea in August/September and in the Caribbean in December. Ambient noise and sound transmission data were obtained which is now in the process of being analyzed using a system developed by the Information Processing Center.

Ocean Structures, Moorings and Materials

The major effort has been engineering support for the Moored Array Program. Twenty-four intermediate depth, twenty-two bottom and eight surface moorings were set out during the year. Two intermediate and one bottom mooring failed. Eight were set to obtain engineering data, four of which were instrumented to provide data relating to mooring motion. One bottom mooring was set and retrieved after one year on station. Six moorings were set by a new method to investigate the feasibility of a "hands-off" automatic deployment scheme.

An analysis of the Woods Hole mooring statistics and performance for the years 1970 and 1971 was conducted in order to define efforts required to improve mooring reliability. One hundred two moorings were set during these years: 35 were surface moorings, 19 intermediate and 48 bottom moorings. Intermediate moorings were the most reliable. Cables and acoustic releases were the major causes of failures.

Plastic armor for the protection of synthetic-fiber mooring lines against fishbite is still under study. The necessary mechanical properties are now well understood, and a specific formulation is being sought. The availability of new ultra-high-strength synthetic fibers adds new impetus to this program, by introducing attractive new possibilities. A mooring line of the new fibers should be of about the same diameter as an equivalent wire rope, but its density should be about the same as that of Dacron. A great improvement in mooring performance is thus promised, and, the very low stretch of the material greatly eases the problems of applying the armor.

A large stable mooring which will be set in the MODE area in 5500 meters water depth with three legs and a heavily instrumented apex 600 meters below the surface was designed and modeled. A special computer program was used in the selection of a design which would meet the scientific requirements of tolerable instrument motion.

The systematic evaluation of specimens of mooring wire materials has yielded a considerable amount of valuable empirical information on the long term performance of bare and jacketed steel and alloy wire ropes and glass fibre rods. Electromechanical cables and their terminations have been traditionally critical components of buoy systems. Two prototypes of torque balanced electromechanical cable and of quick disconnect cable terminations have been designed and set at the "Buoy Farm" south of Cuttyhunk for a one year endurance test.

To provide an increased tracking capability for the long-range SOFAR floats used in the MODE program a listening station was designed and installed at Grand Turk Island, B.W.I. The system consists of a buoyed-up array of four hydrophones connected by electromechanical cable to a shore station 3.5 miles away. Computer programs and mathematical models were devised to evaluate the loads in the cables and the path of the anchor during anchor lowering, the cable pay-out rate as a function of ship speed and bottom topography, and, when implanted, the loads and geometry of the subsurface mooring as a function of current speed. The array was successfully installed in November. Signals from a SOFAR float 400 miles to the north in the MODE area were heard with a signal-to-noise ratio of 10:1.

Acoustics

Acoustics is a tool to many at the Institution for telemetry, navigation, depth sounding, seismic profiling, etc. To others it is a study of sound propagation, ambient noise, coherence, volume reverberation, ray theory and like subjects. The ocean is complex and while we know a lot about acoustics, there are still surprises and difficulties. Ambient noise measurements were made in the North American Basin by CHAIN in February and during September and October, at a total of six locations. ACODAC measurements numbered eleven deployments between June and December or approximately 100 data days. Computer programs have been developed to process the data and plot it.

A major effort was made in long-range low frequency acoustic coherence studies for a better understanding of the spatial and temporal variations of phase and amplitude of the transmissions and the appropriate causal oceanographic environmental factors. The complex motion of moored hydrophones is important in such observations and experiments demonstrated that the motions can be tracked to within four to five centimeters.

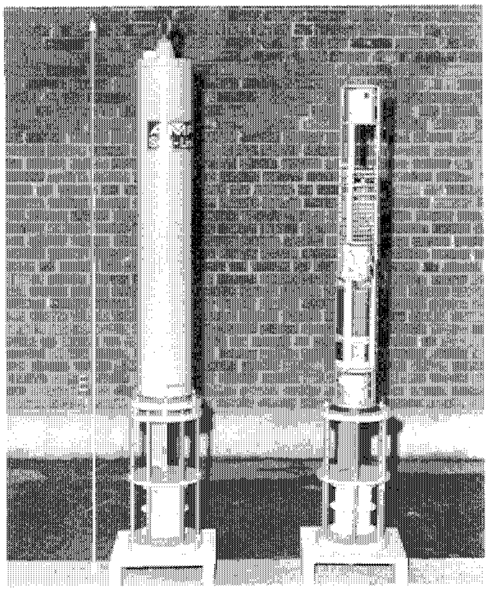
Volume reverberation measurements were made in the North Central Atlantic on a biological cruise. Attempts to correlate the acoustic data with the catch of trawls indicated that it is still not possible to identify marine organisms acoustically with precision.

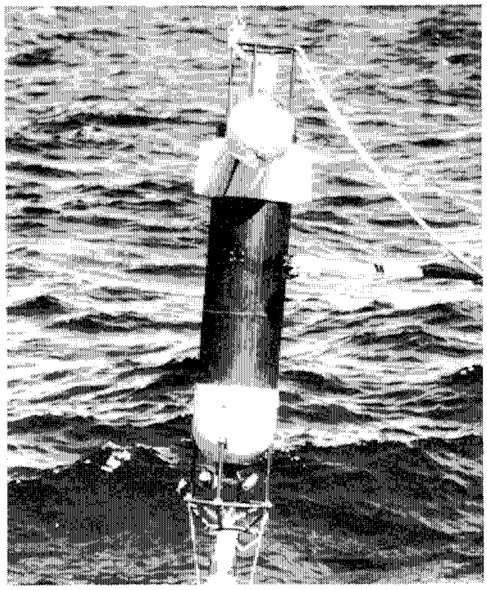
Work continues on the modified ray theory that takes diffraction effects into account. Numerical results indicate that the accuracy of the approximate theory is strongly dependent on the treatment of the caustic which arises in the field. A digital analysis has been assembled this year and is speeding or at least widening the process of data analysis. The system enables one to do so much more than previous systems have, that one naturally extends the analysis.

Safety Program

The safety program continues to depend primarily on individual responsibility and live supervision. A safety inspector has been appointed by the Manager of Facilities to cover shops and buildings as required by the new Occupational Safety and Health Act (of 1970) regulations. The safety engineer reviews on a spot-check basis, investigates potential hazards, and accidents and advises on corrective action. Occasionally it has been necessary to suspend scientific operations because of clear or suspected hazards. This is inevitable and in the long run probably has a salutary effect. Three such suspensions occurred in 1972. One involved the system for attachment of a large instrument to ALVIN and another, the seaworthiness of an industry chartered ship on which our employees were scheduled to work. The third was a chemical etching process performed under unsafe conditions. All other safety problems were resolved early enough to avoid altering cruise schedules or seriously modifying other schedules. There has been increased safety awareness throughout the Institution along with a moderate increase of signs and rules promoting safety.

EARL E. HAYS, *Chairman*





Left: VACM (Vector Averaging Current Meter) Instrumentation for MODE. Right: Free-fall electromagnetic current profiler which obtains vertical profiles of horizontal motions.

Department of Physical Oceanography

There has been a growing feeling among physical oceanographers at Woods Hole and elsewhere that advances in oceanographic methods and understanding might justify a major new attack on the problem of the general circulation of the ocean. Over the last fifteen years measurements in the deep sea have shown that the movement of the ocean rather than being slow and steady, as had been thought, is, in fact, highly variable. The ocean's circulation system is complex, and the physical processes that dominate the motion occur in patterns having a broad spectrum of scales in both time and space.

Mid-Ocean Dynamics Experiment (MODE)

The Physical Oceanography Department has since 1959 provided an increasingly solid picture of the time scales of variable motion in the deep sea. There is dominant energy at the tidal period as well as that at the inertial period related to the rotation of the earth. However, it is motions of time scale much longer than this, weeks to perhaps months, that may play an even more important role in controlling the dynamics of the general circulation of the open ocean.

It is many times easier to define the time scales of motion in the deep sea than it is to define the corresponding space scales. Nevertheless, progress has been made in defining the spatial scales. The low-frequency motions may have space scales of hundreds of kilometers. The currents associated with these patterns, or eddies as they are sometimes called, are relatively weak. Until the development of moored instrumentation and long-lived drifting floats, it was not possible to measure these directly in a statistically meaningful way. When such measurements could be made, it was found that irregular eddy motions can be as much as 100 times more energetic than the mean flow upon which they are superimposed.

In order to make a direct and systematic attempt to measure such mid-ocean, mid-scale motions, the Mid-Ocean Dynamics Experiment, or MODE, is being carried out during the first half of 1973. Members of the Physical Oceanography Department are collaborating with colleagues at many other universities and institutions. During the past year, work has concentrated on obtaining pilot data upon which to base design of the major field experiment called MODE-I.

During 1972, three major arrays of moored current and temperature sensors were installed on moorings in the region selected for MODE-I, about halfway between Bermuda and the Bahamas. The results provide estimates of the spatial scales of the mid-scale eddy motions that are better than those previously available.

Although moored instruments may be the framework around which MODE-I is built, there has been extensive work in the past year on other types of measurements at Woods Hole which will complement the moored array data. New instrumentation to obtain profiles of the horizontal velocity component between the surface and the bottom will be used during MODE-I. In the past year this system has been used during the period of development to examine not only the technique but also the nature of ocean currents. It has been particularly interesting to determine the appropriate averaging needed to produce vertical profiles that give the maximum resolution of velocity while maintaining acceptable accuracy. Part of the work has involved an experiment of 80 velocity profiles at and around Site D (39°10′N 70°W, about 100 miles south of Woods Hole). This experiment was directed at the observation and understanding of wave motions that are dynamically coupled to the sea floor.

Another novel instrument that will be used in MODE-I is a towed set of sensors. This instrument will be towed along behind a research vessel and maintained at a depth of several hundred meters in the main thermocline where the vertical temperature gradients are the greatest. Through measurements of temperature, salinity, and pressure it is possible to control the depth of the instrument so that it follows along a line of constant density. The topography of such a line of constant density, or isopyncnal depth, is one way of defining the eddies in the MODE-I region as manifested in the density field. Both the vertical profiling instrument and the horizontal towed instrument will fill in information between the discrete network of moored instruments.

A third kind of instrumentation that will provide additional basic data will be a set of drifting acoustically-tracked floats. These floats are large, neutrally buoyant vertical cylinders that are ballasted to drift freely at a depth of near 1500 meters. This depth is near the axis of the naturally occurring sound channel in the Atlantic Ocean and SOFAR ranging will be used to track the floats for weeks or even months. The design, construction and testing of the floats has been carried out in the Department of Ocean Engineering. Tests at sea were successful this year. The plans for MODE-I are to use the floats for several months, recover and recharge their batteries, and then relaunch them for a still longer period of observation.

In addition to the experimental field program, theoretical studies aimed directly at an understanding of the dynamics of the processes observed in MODE-I have been underway. Both computer experimentation and theory are being used, and the effects of sloping or rough sea-bottom topography, of density stratification in the ocean, and of large-scale turbulence in balance with the rotation of the earth are included. Computer models that start with a simple pattern of eddies allowed to evolve freely have provided enlightening examples of propagation, fragmentation clustering, and intensification of the eddies, depending on the oceanic conditions included in the model. By such modelling it is hoped to understand the transient flows in the mid-regions of the ocean and thereby to improve the design of experiments like MODE-I and to capitalize on the interpretation of the data that is collected.

The results of MODE-I should have a major influence on the thinking of physical oceanographers about dynamic processes in the deep sea. The area covered and the time-scale of MODE-I are relatively small as compared to the natural time of processes in the ocean. Thus physical oceanographers are beginning to look beyond MODE-I to further cooperative physical oceanographic experiments in a series aimed at understanding the general circulation of the ocean and rational management of the planetary environment.

Moored Array Experiments

In addition to MODE-I, there also are a number of related experiments carried out within the framework of the Moored Array Project. Continuous observations at a location called Site D (39°10′N 70°W) have now been maintained since early in 1965. A long and consistent series of measurements at one spot in the ocean are needed for a reliable description of the irregular movements that are found everywhere in the open ocean. Site D, because of this background of a long time series of measurements, has been chosen as the site for a number of related experiments.

This year an array of moorings was maintained around Site D for most of the year. Since some motions of interest in the region have periods of about one month, an experiment to study them was planned to last about eighteen months. By the end of 1972 only preliminary results were available. Measurements 50 kilometers apart at a depth of 1000 meters show identifiable simultaneous patterns of movement. Occasionally, eddies broken off from the Gulf Stream have passed through the array near Site D. The occurrence of such eddies through an array of instruments may be good for studying the physics of eddies but it obscures the physics of the Rossby waves for which the array was intended. An interesting side effect of the passage of the eddies is the remarkably strong inertial oscillations that are generated.

Improvements in techniques of mooring and instrumentation have sharpened the understanding of the capabilities and limits of current meters. In 1972, significant differences were observed between current meters on moorings having surface floats and moorings having subsurface floats. In the future the limits to which surface float motion can be controlled in its effects on subsurface sensors need to be determined.

Small-scale structure (microstructure) has been the subject of increasing attention by physical oceanographers in the last few years. Our ability to define this structure has recently increased significantly through the use of a precision conductivity-temperature-depth (CTD) digitizer. Such an instrument can be used in the same way as classical oceanographic stations. The availability of this new instrumentation has spawned a fresh examination of the microstructure that is generally found throughout the ocean.

This year saw the beginning of a large experiment designed to learn more about the properties of internal waves in the deep sea. The Internal Wave Experiment (IWEX) is designed to obtain a four-dimensional description of internal waves in the main thermocline in the MODE region. By using the MODE region for the Internal Wave Experiment, it is hoped to build on the body of knowledge about density structure and currents of that area. Three components of velocity and temperature will be measured. A mooring with three legs (tripod mooring) will be set in 5½ kilometers of water. The intensive measurements on the three legs of the mooring will occur between 400 and 800 meters depth in the main thermocline. In order to carry out the experiment in 1973, work must go ahead on instrument development, theoretical studies and the analysis of existing data as a guide to experimental design.

Ocean Circulation

Large-scale descriptive studies of the general circulation of the ocean have always been a major theme of research in the Department of Physical Oceanography. In the past year an extensive investigation of the ocean current system southeast of Newfoundland was carried out in collaboration with scientists from the Bedford Institute of Oceanography in Canada. The purpose of the experiment was to resolve questions concerning the pattern of flow in the region: whether the Gulf Stream splits into two branches or whether the currents that have been observed are really parts of a large-scale, two-gyre circulation. The field work to resolve these questions was carried out in April through June, and involved, in addition to the CHAIN from Woods Hole and the HUDSON from the Bedford Institute, the CIROLANA from Lowestoft in the United Kingdom. Both moored instrumentation and oceanographic stations were carried out during the cruise. An extremely complex pressure, temperature and velocity field was defined in the course of the survey. Analysis by the end of the year had not yet provided an unequivocal answer to the question as to which scheme of ocean current circulation was correct in the region.

Just to the west, the structure of the Gulf Stream as it crosses the 50th meridian, south of the Grand Banks is highly variable. Currents flow both east and west across the section. All available hydrographic station data have been reviewed in an effort to sort out what can be said about the structure of the current. There is clear evidence of cold, relatively fresh water in the Labrador Current at the northern end of the section. Farther south, the accumulated observations can be interpreted in any one of four different ways. A field experiment is planned in the coming year to try to resolve the structure.

The currents on the bottom north of the Bahama Banks have been the subject of considerable speculation, particularly with regard to their possible role in bottom sediment transport. In the past year current meters were set on the northwest portion of the Greater Antilles Outer Ridge north of Puerto Rico. The current pattern revealed a circulation of Antarctic Bottom Water with a flow southeastward along the continental margin, then along bathymetric contours with net southeasterly flow.

The past year saw further progress towards an overall investigation of currents flowing into the Caribbean Sea. There is now a long line of closely spaced observations both inside and outside the arc of the Lesser Antilles, all the way from Puerto Rico to the South American Continental Shelf. Direct current observations at the sill of the passages are of particular interest. Measurements made in the past year at the sill of the Anegada-Jungfern Passage showed a small intermittent flow of water into the Caribbean at the very bottom of the Passage.

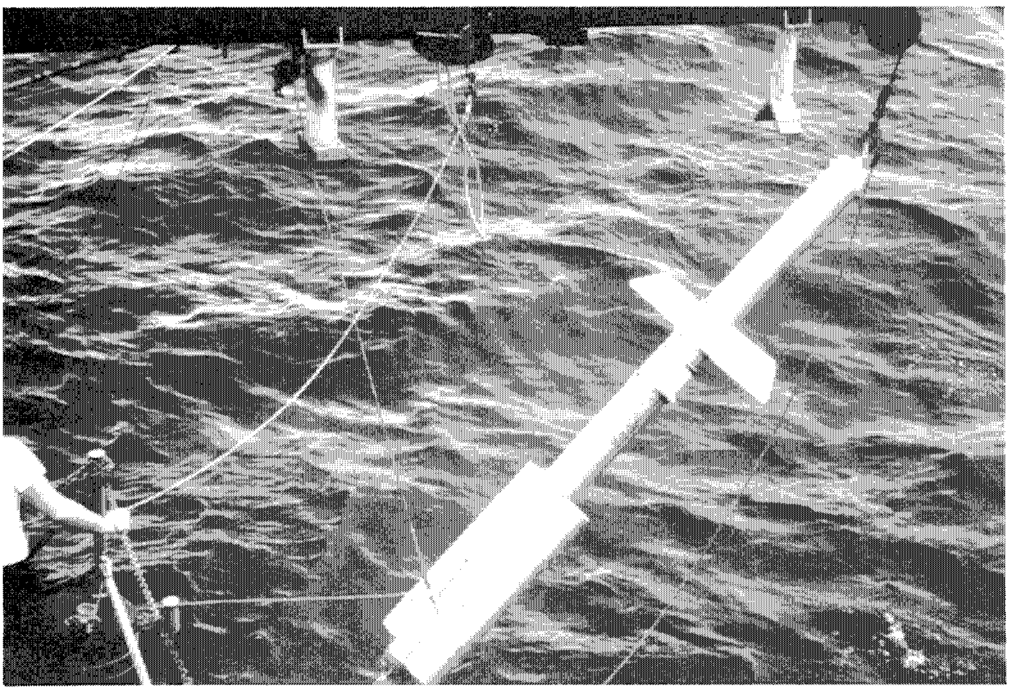
Atmosphere and Ocean

Dr. Jerome Namias spent some time at the Institution in the past year as Rossby Memorial Fellow. During his stay he examined the genesis of Hurricane Agnes as it progressed over the eastern United States in June 1972 causing serious flood-producing storms. Satellite cloud pictures showed that a large advective cloud cluster moved northward from off Peru and apparently formed the nucleus of Hurricane Agnes after colliding with a large mass of cloud at a strong polar outbreak deep in the Gulf of Mexico. The large-scale steering pattern that affected the course of Hurricane Agnes may have been rendered stable for several months by sea surface temperatures in the North Atlantic that were closely coupled with the prevailing wind systems.

The air above the sea has properties and behaves in a way that is sometimes different from the air over land. For many years the properties of the marine atmosphere have been studied by members of the Department. In the past year, aircraft measurements of turbulence, turbulent fluxes, and clouds have been compared with wind profiles obtained from ships. When the oceanic boundary layer is modified by large-scale disturbances, the turbulence varies over a range that is wider than in undisturbed conditions.

The Institution's Hydrodynamic Laboratory facilities are being used in support of many of the theoretical and field programs. Models have been built of the flow through straits and sills in order to understand the dynamics of such flows on the basis of easily observed laboratory analogs. Such flows are a focal point for oceanographers because some of the largest and most intense deep currents occur in the vicinities of straits and sills. New theories, in conjunction with laboratory models, and together with field studies of oceanic sill flows such as those through the Denmark Straits and the Straits of Gibraltar, will lead to further work in this line in the future. The microstructure investigations that were mentioned above in relation to the precision CTD work at sea have been under continuing study as well in the Hydrodynamics Laboratory. An understanding of the mechanisms that generate microstructure might lead to a more direct understanding of the important mechanism of vertical mixing in the ocean.

FERRIS WEBSTER, *Chairman*



SOFAR float, 20-feet long, travels with the current at a depth of about 1500 meters. Its position is traced by shore-based hydrophone arrays.

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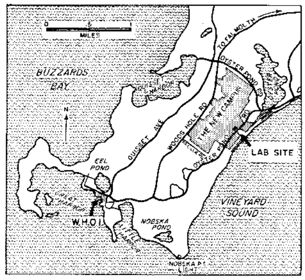
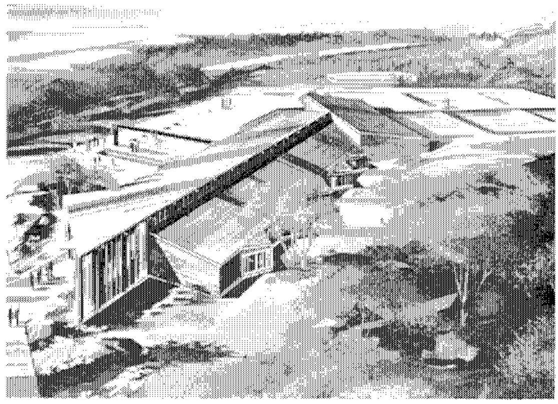


Site of the Environmental Systems Laboratory (ESL).



Architects drawing of the Environmental Systems Laboratory, which has won a national merit award for engineering excellence.

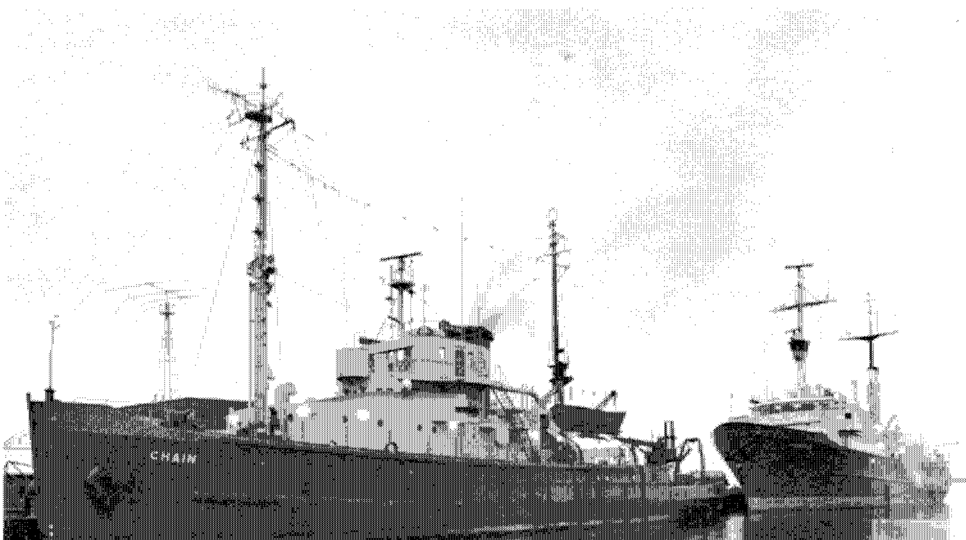
Ashore and Afloat

Ground-breaking for the first major building on the Quissett Campus took place on 1 June 1972. The four-story structure will contain laboratories and offices in some 100,000 square feet of new space. The three-wing building, more than twice the size of the Redfield Building will house some of the work taking place in all departments: on the first floor, there will be suites for the electron microscope and for the acoustics group of the Ocean Engineering Department, a stockroom and a staff workshop; on the second floor there will be the main administrative offices and part of the Department of Geology and Geophysics, on the third floor, there will be space for the Department of Physical Oceanography, and on the fourth floor there will be quarters primarily for the Departments of Biology and Chemistry. A large conference room will be built at the fifth floor level over the central part of the building.

Construction for the new Environmental Systems Laboratory also on Quissett Campus, which will permit more extensive studies in marine aquaculture, began during November 1972. The facility was designed by the firm of Kramer, Chin and Mayo of Seattle. It will be a 4,500 square-foot single-story building with laboratories and an elaborate complex of piping and tanks. Six algae ponds, fifty by fifty feet, will have a surface area of 2,000 sq. ft. and a depth of three feet; the shellfish growing units will provide 2,000 square feet of raceway and the piping system will have an initial capability to filter and heat 500 gallons per minute of sea water.

An oil boom capable of containing up to 5000 gallons of oil in the event of a minor spill in the harbor has been purchased for $1800. Chosen primarily because of its portability, it can be stored in two wooden boxes and loaded quickly onto a skiff in an emergency. It consists of 300 feet of boom, acting as a floating barrier to contain oil. Designed only for inshore use, it sinks to a depth of six inches and can withstand a two-knot tide. After it is put in the water surrounding a spill, the oil can be removed by pump. This equipment has been placed at the disposal of the Steamship Authority, the Biological Laboratory of the U. S. Fisheries Service and the U. S. Coast Guard Station in Woods Hole.

The GOSNOLD, tied up at the dock during the winter, has served the Institution well for more than ten years, particularly in geological surveys of the continental shelf.



Home in time for Christmas!

Cruises - 1972

KNORR Sea/Use Days – 294 Total Miles Sailed – 31,039

VOYAGE NO.	DATES	AREA OF OPERATION	DAYS	CH. SCIENTIST
25 Leg 1	5-16 February	Antilles Outer Ridge		Hollister
25 Leg II	19-20 February	San Juan Local		Sachs
25 Leg III	20 February–4 March	Off Surinam Coast		Sanders
	6-8 March	Passage to San Juan		- - - - -
25 Leg IVa	13-27 March	Caribbean Sea		Metcalf
25 Leg IVb	30 March–14 April	Caribbean Sea		Metcalf
25 Leg IVc	17-26 April	Caribbean Sea		Metcalf
25 Leg V	30 April–9 May	Atlantic Ocean	95	Stalcup
26	17 May–5 June	Site D, J, L–MODE– Muir Seamount	20	Gifford
27	8-9 June	Offshore, Cape Cod	2	Hollister
28	11-19 June	Shipyard–New York	–	- - - - -
29	4-6 July	Off East Coast	3	Spencer
	7-13 July	Off East Coast	7	Spencer
30 Leg I	18 July–7 August	North Atlantic		Spencer
30 Leg II	12-30 August	Northern N. Atlantic		Spencer
30 Leg III	4 September–1 October	North Atlantic		Broecker
30 Leg IV	9-31 October	North and South Atlantic		Craig
30 Leg V	4-28 November	South Atlantic		Broecker
30 Leg VI	4-22 December	South Atlantic		Park
30 Leg VII	30 December–	Southern S. Atlantic	167	Craig

GOSNOLD Sea/Use Days – 120 Total Miles Sailed – 11,489

VOYAGE NO.	DATES	AREA OF OPERATION	DAYS	CH. SCIENTIST
186	3-11 April	Boston–Shipyard	–	- - - - -
187	16-20 April	Off East Coast	5	Rowe
188	25 April–4 May	Gulf of Maine	10	Ballard
189	16-20 May	South of Cape Cod	5	MacIlvaine
190 Leg I	29-31 May	Continental Shelf	3	Wright
190 Leg II	1-2 June	Continental Shelf	2	Wright
191	7-16 June	Bottom Station 1	10	Hampson
192	22-29 June	Bermuda & return	8	Deuser
193	5-9 July	Gulf Stream	5	Williams
194	10-14 July	Site D	5	Tupper
195	19-28 July	Gulf of Maine	10	Uchupi
196	2-6 August	Site D	5	Sanford
197	9-18 August	Bottom Station 1	10	Haedrich
198 Leg I	21 August–1 September	Site D	12	Sanford
198 Leg II	4-8 September	Site D	5	Sanford
	9-15 September	Site D	7	Sanford
199	20-21 September	Bottom Station 1	2	Holmes
	23-29 September	Bottom Station 1	7	Holmes
200	4-7 October	Bottom Station 1	4	McLellan
	10-13 October	Bottom Station 1	4	McLellan
201	16 October	Gay Head	1	Driscoll

LULU Sea/Use Days – 192 Total Miles Sailed – 6,746

VOYAGE NO.	DATES	AREA OF OPERATION	DAYS	CH. SCIENTIST
49	12-21 January	Transit to Florida		Walden
	26 January–3 February	Florida Waters		Walden
	7-10 February	Florida Waters		Walden
	12-16 February	Florida Waters		Walden
	21-24 February	Florida Waters		Walden
	25 February–2 March	Florida Waters	51	Walden
	3 March	To shipyard–Florida	–	- - - - -
	27 March	Return from yard	–	- - - - -
	28 March–17 April	Florida Waters		Walden
	19-26 April	Transit to Boston Shipyard	30	- - - - -
	2-3 May	Return to Woods Hole	–	- - - - -
50	16-20 May	Continental Slope	5	Rainnie

LULU (continued)

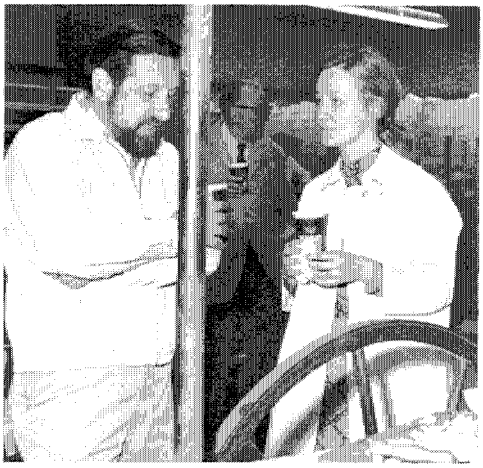
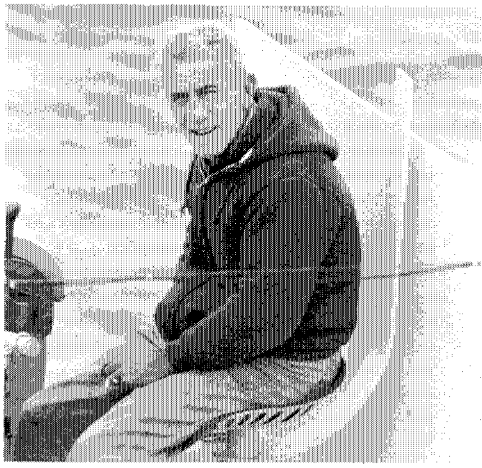
VOYAGE NO.	DATES	AREA OF OPERATION	DAYS	CH. SCIENTIST
51	26 May–2 June	Gulf of Maine	8	Williams
52	7-16 June	Bottom Station 1	10	Grassle
53	23 June–1 July	Hudson Canyon	9	Keller
54	6-15 July	Gulf of Maine	10	Marquet
55	19-28 July	Gulf of Maine	10	Ballard
56	9-18 August	Bottom Station 1	10	Rowe
57	23 August–1 September	Gulf of Maine	10	Bryan
58	6-15 September	Hudson Canyon	10	Keller
59	20-22 September	Bottom Station 1	3	Sanders
	23-29 September	Bottom Station 1	7	Sanders
60	4-7 October	Bottom Station 1	4	Grassle
	8-13 October	Bottom Station 1	6	Grassle
61	18-26 October	Massachusetts Bay	9	Williams/Rainnie

CHAIN Sea/Use Days – 279 Total Miles Sailed – 32,672

VOYAGE NO.	DATES	AREA OF OPERATION	DAYS	CH. SCIENTIST
101	29 January–14 February	70° Transect & MODE	17	Heinmiller
102	18 February–7 March	West of Bermuda	19	Nowak
103	11-26 March	70° Transect	16	Moller
104 Leg I	4-15 April	Western N. Atlantic		Warren
104 Leg II	16 April–5 May	Western N. Atlantic		Warren
104 Leg III	11-30 May	Western N. Atlantic		Worthington
104 Leg IV	1-9 June	Western N. Atlantic	67	Worthington
	12-21 June	Shipyard–Newfoundland	–	- - - - -
105 Leg I	24 June–16 July	North Atlantic		Backus
105 Leg II	20 July–12 August	North Atlantic		Backus
106	15 August–6 September	North Atlantic	75	Grassle
106-II	15 September–2 October	West of Bermuda		Porter
	5-18 October	West of Bermuda	34	Spindel
107	22 October–10 November	70° Transect	20	Gifford
108	13-27 November	MODE Site	15	Voorhis
109	4-19 December	Site D	16	Tupper

ATLANTIS II Sea/Use Days – 308 Total Miles Sailed – 46,352

VOYAGE NO.	DATES	AREA OF OPERATION	DAYS	CH. SCIENTIST
67 Leg I	20 January–2 February	West Coast of Africa and Deep Sea East of Middle Atlantic Ridge		Uchupi
67 Leg II	4-22 February	Same as preceding		Uchupi
67 Leg III	27 February–20 March	Same as preceding		Uchupi
67 Leg IV	24 March–8 April	Same as preceding		Emery
67 Leg V	12 April–6 May	Same as preceding		Milliman
67 Leg VI	10-30 May	Same as preceding		Emery
67 Leg VII	4 June–1 July	Same as preceding		Emery
68 Leg I	7-28 July	South Atlantic		Knox
68 Leg II	31 July–15 August	Passage to Woods Hole	209	- - - - -
69	22 August–5 September	70°W Transect	15	Moller
70	11-14 September	Shipyard–Boston	–	- - - - -
71 Leg I	20-29 September	Northwest of Bermuda		Teal
71 Leg II	1-15 October	Northwest of Bermuda	26	Teal
72	20 October–7 November	Continental Slope	19	Ross
73 Leg I	11-29 November	Mid Atlantic Ridge		Phillips
73 Leg II	1-19 December	Mid Atlantic Ridge	39	Stetson

Interlude — "ashore" and "afloat".

Scientific Departments and Supporting Services Personnel

PAUL M. FYE	Director
ARTHUR E. MAXWELL	Provost
H. BURR STEINBACH	Dean of Graduate Studies
ROBERT W. MORSE	Director of Research
BOSTWICK H. KETCHUM	Associate Director
DAVID D. SCOTT	Assistant Director for Administration
FREDERICK E. MANGELSDORF	Assistant Director

The following were in the employ of the Institution on December 31, 1972.

Department of Biology

Anderson, Susan J.
Backus, Richard H.
**Beebe-Center, Roxanne
Bowman, Pamela E.
*Brady, Cheryl Lynette
Broda, James E.
*Brown, Anna
Browne, Mason G.
Carey, Francis G.
*Carlson, Craig
Carpenter, Edward J.
*Clarke, George L.
Clarner, John P.
*Cleary, Dana
Clifford, Charles H.
Cole, Linda M.
Collins, Anne C.
Corwin, Nathaniel
Craddock, James E.
Flanagan, James D.
Franklin, Denise
Garner, Susan P.
Goldman, Joel C.
Gonye, Edward R., Jr.
Goodrich, Virginia L.
Grassle, J. Frederick
Grice, George D., Jr.
Guillard, Robert R. L.
Gunning, Anita H.
Haedrich, Richard L.
*Halderman, Lauri A.
Hampson, George R.
Harbison, G. Richard
Holmes, Paul E.
Hopf, Mark
Huguenin, John E.
Hulburt, Edward M.
*Hulburt, Joan B.
Jacobs, S. Andrew
Jannasch, Holger W.
**Johnson, Thomas A.
Judkins, David C.
Kanwisher, John W.
Kerfoot, William B.
Konnerth, Andrew, Jr.
Lawson, Kenneth D., Jr.
Lawson, Thomas J., Jr.
Linton, Catherine
Mason, John M., Jr.
Masch, David W.
Mather, Frank J. III
*McCullough, Coyla B.
Mogardo, Juanita A.
*Murphy, Lynda S.
Nairn, Robert J.
Peck, Bradford
*Polloni, Pamela
Prince, Jeffrey S.
Quinby, Helen L.
Remsen, Charles C. III
Robison, Bruce H.
Rogers, M. Dorothy
Rowe, Gilbert T.
Ryther, John H.
Sanders, Howard L.
Scheltema, Rudolf S.
*Schevill, William E.
Schroeder, Brian W.
Sears, Mary
Sheran, Kathleen A.
Shores, David L.
Smith, Kenneth L., Jr.
Stanley, Helen I.
Stegman, John J.
**Sunda, William G.
Tarala, Erica J.
Teal, John M.
Tenore, Kenneth R.

*Part Time Employment **Temporary Employment

Department of Biology (continued)

Tuttle, Jon H.
Vaccaro, Ralph F.
Valois, Frederica W.
Vreeland, Valerie
Watkins, William A.
Watson, Stanley W.
Wiebe, Peter H.
Williams, Isabelle P.
Wing, Asa S.
Wirsen, Carl O., Jr.

Department of Chemistry

*Angevine, Charles L.
Antonellis, Blenda
Atema, Jelle
Bankston, Donald C.
**Barbour, Courtenay
Blumer, Max
Bourbonniere, Richard A.
Bowen, Vaughan T.
Bowker, Paul C.
Brewer, Peter G.
Burke, John C.
Chang, Wen-Man
Degens, T. Egon
Dempsey, Brenda L.
Densmore, C. Dana
Deuser, Werner G.
*Dorsey, Thomas F., Jr.
Farmer, John G.
Farrington, John W.
*Fennelly, A. Olga
Fettis, Richard C.
Frew, Nelson M.
Gagosian, Robert B.
Gordon, Allan G.
*Goudreau, Joanne E.
Graham, Linda B.
Green, Nancy H.
Gregory, Sandra
Harvey, George R.
*Hess, Marilyn R.
Hunt, John M.
Jacobson, Stewart M.
Johnson, Christine N.
*Johnson, Fritz
Jouris, William E.
Kadar, Susan
Laking, Phyllis N.
Lawson, Charlotte M.
Livingston, Hugh D.
MacKenzie, Susan M.
Mahoney, John W.
*Mandigo, Paul D.
**Mangelsdorf, Paul C.
Mann, Don R.
McAuliffe, Julianne G.
McLarney, William O.
Miklas, Helen P.
Mitchell, Joan R.
**Murray, James W., Jr.
Olson, Charles A.
Price, N. Brian
*Robinson, E. Arthur, Jr.
Ross, Edith
Sachs, Peter L.
Sass, Jeremy
Sayles, Fred L.
Schneider, David L.
Smith, Clarence L.
Spencer, Derek W.
Stein, Lauren S.
Steinhauer, William G.
Surprenant, Lolita D.
Thompson, Geoffrey
Todd, John H.
Tripp, Bruce W.
Van Cleave, Marguerite E.
Waterman, Lee S.
Zafiriou, Oliver C.

Department of Geology and Geophysics

Aldrich, Thomas C.
Allison, Donna F.
Antanavage, Joanne
Ballard, Robert D.
Beckerle, John C.
Berggren, William A.
Boersma, Anne
Bowin, Carl O.
Bryan, Wilfred B.
Bunce, Elizabeth T.
Connell, John F.
*Coppenrath, Agnes I.
Dale, Barrie
Davies, Rodman F.
de Castellane, Romeyn P.
Dow, Willard
Driscoll, Alan H.
Dunkle, William M., Jr.
Ekstrom, Kenneth D.
Ellis, Jeffrey P.
Emery, Kenneth O.
Erickson, Albert J.
Fillon, Richard H.
Forrestel, Frances A.
*Gallagher, Gloria S.
Goldsborough, Robert G.
Gove, Leon A.
Grant, Carlton W., Jr.
Groman, Robert C.
Handy, Robert E.
Haq, Bilal ul
Hathaway, Dana B.
Hays, Helen C.
Hecky, Robert E.
Heirtzler, James R.
**Hennemuth, Bradley J.
Hess, Frederick R.
Hollister, Charles D.
Honjo, Susumu
Hoskins, Hartley
Johnson, David A.
*Jones, Maxine
**Kenah, Christopher
Kertyzak, Michael J.
Knott, Sydney T., Jr.
Koelsch, Donald E.
Koons, Mary-Linda
Luyendyk, Bruce P.
**MacIlvaine, Joseph C.
Mellor, Florence K.
Milliman, John D.
Morehouse, Clayton B.
Mosier, Gatha A.
Mountain, Gregory S.
Nafe, Katharine E.
Nichols, Walter D.
Nowak, Richard T.
Okada, Hisatake
Owen, David M.
*Peters, Virginia B.
Phillips, Joseph D.
*Poole, Stanley E.
*Powers, Andrea
Premoli-Silva, Isabella
Richards, Deva
Riley, Anne S.
Ross, David A.
Ruiter, Robert G.
**Schmidt, Dennis W.
Serotkin, Nancy G.
**Shaughnessy, Daniel R.
*Shephard, Frank C.
Simkins, Samuel T.
Spindel,, Robert C.
Stetson, Thomas R.
**Steward, Robert G.
Stone, Louise D.
Summerhayes, Colin P.
Sutcliffe, Thomas O. L.
*Swenson, Lynn V.
Toner, Lois G.
**Tucholke, Brian
Uchupi, Elazar
Unda, Carolyn D.
Vine, Allyn C.
von der Heydt, Keith
Von Herzen, Richard P.
Wall, David
**Wilder, Stephen S.
Witzell, Grace M.
Witzell, Warren E.
Wooding, Christine M.
Young, Earl M., Jr.

*Part Time Employment **Temporary Employment

Department of Physical Oceanography

The crew of the KNORR named James E. Gifford (right) "Chief Scientist of the Year". The award was presented by Alden H. Cook.

Alexander, Robert M.
*Allen, Ethel B.
Armstrong, Harold C.
Bailey, Phyllis T.
Barbour, R. Lorraine
Bradshaw, Alvin L.
Breivogel, Barbara B.
Briscoe, Melbourne G.
Bruce, John G., Jr.
**Bryden, Harry L.
Bumpus, Dean F.
Bunker, Andrew F.
Chase, Joseph
Chausse, Dolores H.
Cornell, Margaret C.
Csanady, Gabriel T.
Daly, Kathleen
Day, C. Godfrey
Dean, Jerome P.
Dunlap, John H.
Ewing, Gifford C.
Fofonoff, Nick P.
Frank, Winifred H.
Frazel, Robert E.
Fuglister, Frederick C.
Gaffron, Barbara P.
Gifford, James E.
Guillard, Elizabeth D.
Harlow, Caroline
Hayes, Stanley P.
Heinmiller, Robert H.
Horn, William H.
Joyce, Terrence M.
Katz, Eli J.
Knapp, George P. III
LaRochelle, Roderigue A.
Luyten, James R.
Maltais, John A.
McCullough, James R.
Metcalf, William G.
Millard, Robert C., Jr.
Miller, Arthur R.
Moller, Donald A.
**Monget, Jean-Marie
Moore, Douglas E.
**Noble, Marlene E.
Parker, Charles E.
Poirier, Joseph R.
Reese, Mabel M.
Rhines, Peter B.
**Ruddick, Barry
Sanford, Thomas B.
Saunders, Peter M.
Scharff, John M. III
Schleicher, Karl E.
Schmitz, William J., Jr.
Schroeder, Elizabeth H.
Simmons, William F.
Simoneau, R. David
Soderland, Eloise M.
Spencer, Allard T.
Stalcup, Marvel C.
Stanley, Robert J.
Stratton, Joyce B.
Tarbell, Susan A.
Thompson, Rory
Tupper, George H.
Volkmann, Gordon H.
von Arx, William S.
Voorhis, Arthur D.
Warren, Bruce A.
Webster, Ferris
Whitehead, John A., Jr.
Whitney, Geoffrey G., Jr.
Williams, Audrey L.
*Wilson, Penelope
Worthington, L. Valentine
Wright, W. Redwood
*Ziegler, Evelyn L.
Zemanovic, Marguerite E.
Zwilling, Avron M.

Department of Ocean Engineering

Adams, James M.
Aldrich, Thomas B.
Bardsley, Brian L.
Barrs, Andrew F.
Barstow, Elmer M.
Bartlett, Arthur C.
Baxter, Lincoln II
Benoit, Raymond R.
Bento, Joseph, Jr.
Bergstrom, Stanley W.
Berteaux, Henri O.
Bitterman, David S.
Bland, Edward L., Jr.
Boutin, Paul R.
Brereton, Richard S.
Broderson, George deP.
Brown, Neil L.
Burt, Kenneth H.
Butler, James
Chute, Edward H.
Cole, Bruce R.
Collins, Clayton W., Jr.
Connell, William L.
Crook, Thomas
Davis, James A.
Deane, Stanley R.
Denton, Edward A.
Derouin, Donald E.
Dexter, Stephen C.
Doherty, Kenneth W.
Donnelly, John D.
Dorson, Donald L.
‡Doutt, James A.
Drever, Robert G.
*Dunworth, Jane A.
Eggleston, Fred S., Jr.
Eliason, Andrew H.
Evans, Emily
Fairhurst, Kenneth D.
Foster, Dudley B.
Frank, Eric H., Jr.
**French, John P.
Freund, William F., Jr.
Gibson, George W.
Glass, Gordon K.
Goff, William E.
Goldsmith, Roger A.
**Gough, Edward C.
Graham, Russell G.
Hardy, Carl C.
Hartke, Richard A.
Hays, Earl E.
**Hendricks, Peter
Hilliard, Channing N., Jr.
Hosom, David S.
Hunt, Mary M.
**Jaffee, Richard J.

*Part Time Employment **Temporary Employment ‡On Leave of Absence

Department of Ocean Engineering (continued)

Kallio, Peter E.
Koehler, Richard L.
Kucharski, William M.
Lenart, Alice L.
Lim, Harold K.
Lyon, Thomas P.
Machado, Richard A.
Marquet, William M.
Mason, David H.
Mavor, James W.
McCamis, Marvin J.
McElroy, Marguerite K.
McElroy, Paul T.
McLeod, John W.
Meier, George A.
Morton, Alfred W.
Murray, Paul C.
Muzzey, Charlotte A.
O'Brien, Thomas F.
O'Malley, Patrick
**O'Sullivan, James F.
Penton, Ronald
**Pickett, David M.
Pires, Karen
Polloni, Christopher F.
Porteous, John
Porter, Robert P.
Power, George H.
Rainnie, William O.
Roberts, William P.
*Ronne, F. Claude
Rosenfeld, Melvin A.
Sharp, Arnold G.
Shepard, George W.
Shultz, William S.
**Simonetti, Paul J.
Smith, Woollcott K.
Stanbrough, Jess H., Jr.
Stephen, Theresa F.
Stern, Margaret P.
Stimson, Paul B.
Striffler, Foster L.
Stuermer, Elizabeth A.
*Sullivan, James R.
Tollios, Constantine D.
Wagner, Kenneth N.
Walden, Barrie B.
Walden, Robert G.
Walen, Roger S.
Webb, Douglas C.
Webster, Jacqueline H.
Williams, Albert J. 3rd
Wilson, Valentine P.
Winget, Clifford L.
Witzell, Warren E., Jr.
Woods, Donald E.

Department of Administrative and Service Personnel

Aiguier, Edgar L.
Anders, Wilbur J.
Andrews, Paula M.
Barnes, Susan M.
Battee, Howard
Battee, Janice R.
Behrens, Henry G.
Black, Ruth L.
Botelho, Eleanor M.
Bourne, Wallace T.
Bowman, Richard W.
Brauneis, Frederick A.
Breivogel, Richard J.
Brown, John W.
Busa, Kathryn
Cadwalader, George
Campbell, Eleanor N.
Carlson, Gustaf A.
Carver, Kenneth W.
Casiles, Phyllis
Chalmers, Agnes C.
Charette, Ernest G.
Christian, John A.
Clark, Philip
Clemishaw, Charles W.
Clough, Auguste K.
Coneybear, Edna W.
Conway, George E.
Corr, James P.
Costa, Arthur
Crawford, Bruce
Creighton, James E.
Crocker, Marion W.
Croft, Donald A.
Crouse, Porter A.
Czerwonka, Anita M.
Dastous, Roland L.
Davis, Frances L.
*Davis, Ruth H.
Dean, Mildred J.
DeLisle, Homer R.
DeSanti, Judith C.
Dimmock, Richard H.
Dinsmore, Robertson P.
Dutra, Leslie
Eastman, Arthur C.
Edwards, Richard S.
Farrell, Barbara J.
Ferreira, Anthony
Fernandes, Alice P.
Fielden, Frederick E.
Fisher, Stanley O.
Fredriksen, Mauritz C.
*Fuglister, Cecelia B.
*Gallagher, William F.
Gandy, Curtis
Gassett, Kenneth H.
Gibson, Laurence E.
Halle, Rene C., Jr.
Hampton, Carolyn S.
Harbison, Linda N.
Hatzikon, Kaleroy L.
Henderson, Arthur T.
Hindley, Robert J.
*Hodgman, Elizabeth R.
Hodgson, Sloat F.
Holcomb, Frank E.
Ingram, Ruth C.
Innis, Charles S., Jr.
Jenkins, Delmar R.
Johnson, Harold W.
Johnson, Joanne P.
Joseph, Charles R.
Kelley, Robert F.

*Part Time Employment **Temporary Employment

Ruth H.E. Carlson

Frederick E. Fielden (in Apr. 1973)

Stanley E. Poole

Carl R. von Dannenberg

Retirees in '72

Department of Administrative and Service Personnel (continued)

Kempton, Edward F.
King, Lauriston R.
Koval, Frank
Lajoie, Therese S.
LeBlanc, Donald
Leiby, Jonathan
*Livingston, Stella J.
Lowe, Robert G.
Lumsden, George W.
MacKillop, Harvey
MacLeish, William H.
Mahut, Odette
Marks, Cynthia A.
Martin, Olive
Matthews, Francis S.
Mayberry, Ernest H.
McCleary, John D.
McComb, Patricia S.
McGilvray, Mary K.
McLarnon, Beth L.
Medeiros, Frank
Meinert, Dorothy
Mendousa, Anthony G.
Merson, Carole R.
Miller, Carolyn
Mitchell, James R.
*Momm, Albert O.
Motta, Joseph F.
Mullen, Carolyn G.
Muller, John T.
Murphy, Joan E.
Norwood, Roberta
Oakes, Harry E.
Ortolani, Mary
Page, Stephen G.
Peirson, A. Lawrence III
Peters, Charles J., Jr.
Phares, Edward
Picard, Eleanor P.
Pike, John F.
*Posgay, James
Prinslow, Carole C.
Pucci, Joseph F.
Pykosz, Patricia A.
Quigley, Alexsandra
Quigley, Ralph W.
Ramsey, William S., Jr.
Reeves, A. Stanley
Rennie, Thomas D.
Rice, William T.
Robbins, Charles C.
Robinson, Christine C.
Robitaille, W. H.
Ross, David F.
Rudden, Robert D., Jr.
Ruffen, Kenneth T.
Schilling, John L.
Schneider, Frederic W.
Schneider, Gloria F.
Schofield, Michael G.
Scott, David D.
*Sharpe, Michael S.
Singer, Joseph M.
Smart, Thomas H. M.
Soares, Susan J.
Souza, Donald P.
Souza, James H.
Souza, Thomas A.
Staltare, Michelle E.
Stimpson, John W.
Swan, James A.
*Swan, Jeanne G.
Taylor, Mildred L.
Thayer, Mary C.
Thomas, Patricia A.
Thompson, Martha J.
*Thompson, Patricia E.
Vail, Stanley F.
Vallesio, Barbara M.
Walker, Jean D.
Wallace, Deena M.
Watson, L. Hoyt
Webert, Warren F.
Weeks, Robert G.
Wege, Jane P.
Wessling, Andrew L., Jr.
White, Haskel E.
White, Ralph W.
Wing, Carleton R.
Woodward, Fred C., Jr.
Woodward, Martin C.
Woodward, Ruth F.
Young, Carleton F.
Zwinakis, Jeffrey A.

Marine Personnel

Anderson, Thomas L.
Babbitt, Herbert L.
Baker, William R.
Bauerline, Gunter
Bazner, Kenneth E.
Bizzozero, John P.
Brennan, Edward J.
Brodrick, Edward R.
Bumer, John Q.
Butler, Dale T.
Caranci, Donald H.
Carignan, David W.
Casiles, David F.
Chamberlin, J. Mark
Chretien, Alfred J.
Clark, Robert W., Jr.
Clarkin, William H.
Cochran, Patrick F.
Colburn, Arthur D., Jr.
Cook, Alden H.
Cotter, Jerome M.
‡Coughlin, Brooks
**Crocker, John D.
**Cycz, Paul S.
‡Davis, Charles A.
**Dawicki, Joseph F., Jr.
Densmore, Chauncey
Doherty, William H.
Dunn, Arthur J.
**Elderkin, Donald R.
Ellis, Kenneth R.
Farnsworth, Donald C.
Farris, Ralph W.
Field, Michael J.
Flaherty, Peter M.
Flegenheimer, Richard C.
Gamble, Norman D.
Gassert, John M.
Gordon, Robert L.
Graca, Francisco T.
Hartke, David L.
Hennemuth, Jeffrey C.
Higgins, Paul R.
Hiller, Emerson H.
Hodgkins, Philip W.
Holway, Roy R.
Howland, Paul C.
Jefferson, Albert C.
Jeglinski, James F.
Jenks, Frederick C. III
Johnston, Alexander T.
Knight, Olin T.
LaPorte, Leonide
Lobo, Wayne F.
Macomber, Edward F.
‡Macomber, William G.
Manley, Thomas F.
‡Martin, John W.
**Martin, Ralph, Jr.
Masters, Charles E. III
McDaniel, Stanley O.
McLaughlin, Barrett H.
McMurray, Robert H.
Medeiros, Alfred F., Jr.
Moye, William E.
Munns, Robert G.
Mysona, Eugene J.
Nicoll, David J.
Ocampo, Conrad H.
O'Neil, Thomas F.
O'Reilly, Peter P.
Palmieri, Michael
Patton, Mark E.
Peck, Jeffrey P.
Pierce, George E.
Pierce, Samuel F.
Pineo, Otis H.
Ribeiro, Joseph
Rioux, Raymond H.
Roderick, John P.
Rodgers, Roger
Rougas, Harry
Sainz, Alfonso B.
Seibert, Harry H.
Sequeira, Jorge A.
Sheak, Robert E.
Smith, Allan D.
Smith, Martin G.
Smith, Robert E.
Soucy, Trefton A.
Stack, William M.
Stires, Ronald E.
Sture, Armas V.
Sweet, John K., Jr.
Tucker, Stephen C.
Turton, Alden D.
Vieira, Jesse P.
**Warecki, Joseph
‡Westberg, Donald R.
Whitehouse, Arnold A.

*Part Time Employment **Temporary Employment ‡On Leave of Absence

A group of Soviet oceanographers spent two days in Woods Hole discussing future cooperative projects under a new U.S.A.-U.S.S.R. Agreement for Cooperation in Science and Technology.

A Coast Zone Workshop was held in Woods Hole, 22 May–3 June 1972. A book "The Water's edge: critical problems of the coastal zone" edited by Bostwick H. Ketchum has already been published as a consequence.

Treasurer's Report

The Financial Statements for the year 1972 have been audited by Lybrand, Ross Bros. and Montgomery.

Total Operating Expenses increased 18% over 1971. The major increases occurred in the following categories:

	1972	1971	Increase
Direct Costs of Research	$14,274,000	$12,080,000	18%
Graduate Studies Program	639,000	517,000	24%
General & Administration	1,710,000	1,446,000	18%

A comparison of the Endowment Fund for the years 1972 and 1971 is as follows:

	1972	1971	Increase
Assets at Book Value	$26,745,000	$21,183,000	26%
Assets at Market Quotations	38,685,000	32,151,000	20%
Additions to Principal	16,000	4,435,000	
Total Income Received	683,000	422,000	62%

Other statistics of interest are:

	1972	1971	Increase
Gross Payroll	$ 7,960,000	$ 7,037,000	13%
Retirement Trust Contribution	634,000	559,000	13%

Gifts and Grants from the 659 Individual, Corporate and Club Associates, together with those from other private sources totalled $2,012,000.

The Quisset Campus Development Program started 1972 with a balance of $83,198 which was increased during the year by receipts totalling $996,589. Costs incurred during the year amounted to $740,462 leaving an unexpended balance of $339,325 at year end. Expenditures required to complete the project are estimated at $6,600,000, of which $5,520,000 was committed at 12/31/72. Outstanding pledges at December 31, 1972 totalled $2,760,500.

Audited Financial Statements appear on the following pages.

Edwin D. Brooks, Jr.
Treasurer

Auditor's Opinion

To the Board of Trustees of

Woods Hole Oceanographic Institution:

We have examined the balance sheet of Woods Hole Oceanographic Institution as of December 31, 1972 and the related statements of changes in funds and of operating expenses, transfers and resources used to meet operating expenses 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. We previously examined and reported upon the financial statements for the year ended December 31, 1971.

In our opinion, the aforementioned statements (with investments stated at cost) (pages 85 and 86 and Notes to Financial Statements on page 87) present fairly the financial position of Woods Hole Oceanographic Institution at December 31, 1972 and 1971, its operating expenses, transfers and resources used to meet operating expenses for the years then ended, and the changes in funds for the year ended December 31, 1972, in conformity with generally accepted accounting principles applied on a consistent basis.

The supplemental schedule included in this report, (page 87) although not considered necessary for a fair presentation of the financial position and results of operations, is presented primarily for supplemental analysis purposes. This additional information has been subjected to the audit procedures applied in the examination of the basic financial statements, and in our opinion, is fairly stated in all material respects in relation to the basic financial statements taken as a whole.

Boston, Massachusetts
March 23, 1973

Lybrand, Ross Bros. & Montgomery

BALANCE SHEETS

December 31, 1972 and 1971

ASSETS

	1972	1971
Current Fund Assets:		
Cash	$ 397,389	$ 790,091
Short-term investments, at cost which approximates market	3,100,015	975,024
Reimbursable research costs:		
Billed	705,945	1,498,726
Unbilled	1,126,563	801,676
Supplies, prepaid expenses and deferred charges	383,265	275,878
Plant funds advanced to current funds	(2,427,195)	(1,454,157)
Endowment funds due to current funds	37,260	26,752
	3,323,242	2,913,990
Endowment Fund Assets (Note A):		
Investments:		
Securities, at cost (market value $38,295,202 in 1972 and $31,035,940 in 1971)	26,355,745	20,067,981
Real estate	52,440	52,440
	26,408,185	20,120,421
Cash (including $250,000 certificate of deposit in 1972)	363,298	1,068,946
Other assets	11,038	20,000
Endowment funds due to current funds	(37,260)	(26,752)
	26,745,261	21,182,615
Plant Fund Assets:		
Laboratory, plant and equipment	6,328,426	6,148,065
Atlantis II, contingent title (Note C)	4,831,130	4,831,130
Other vessels, equipment and property	3,587,167	3,604,344
Construction in progress	1,041,698	180,212
	15,788,421	14,763,751
Less accumulated depreciation	4,389,613	3,766,395
	11,398,808	10,997,356
Plant funds advanced to current funds	2,427,195	1,454,157
	13,826,003	12,451,513
	$43,894,506	$36,548,118

LIABILITIES

	1972	1971
Current Liabilities and Reserves:		
Accounts payable and accrued expenses	$ 840,867	$ 714,857
Contribution payable to employees' retirement plan and trust (Note E)	633,892	558,909
Unexpended balances of restricted gifts and grants	560,535	389,789
Reserves	1,287,948	1,250,435
	3,323,242	2,913,990
Endowment Funds (Notes A and B):		
Restricted as to principal and income	9,140,400	9,140,400
Restricted as to principal	2,522,696	2,522,696
Unrestricted as to principal; restricted as to income	6,255,551	6,242,074
Unrestricted as to principal and income	161,851	158,952
Accumulated net gain on sales of investments (including $5,201,383 related to funds, restricted as to principal and income)	8,664,763	3,118,493
	26,745,261	21,182,615
Plant Funds (Note F):		
Expended for plant, less retirements	15,788,421	14,763,751
Less accumulated depreciation	4,389,613	3,766,395
	11,398,808	10,997,356
Unexpended	2,427,195	1,454,157
	13,826,003	12,451,513
	$43,894,506	$36,548,118

The accompanying notes are an integral part of the financial statements.

Statement of Operating Expenses, Transfers and Resources Used to Meet Operating Expenses

for the years ended December 31, 1972 and 1971

	1972	1971
Operating Expenses and Transfers:		
Direct costs of research activity:		
Salaries and wages	$ 4,899,912	$ 4,163,754
Vessel operations	3,414,312	3,249,991
Materials, equipment and services	3,863,249	2,953,062
Laboratory costs	807,985	669,172
Travel	393,981	310,224
Service departments	377,348	350,671
Computer center	516,898	383,143
	14,273,685	12,080,017
Direct costs of educational operations:		
Fellowships	336,856	317,291
Other operating costs	362,273	290,314
	699,129	607,605
Indirect costs:		
General and administrative	1,709,524	1,446,211
Depreciation expense, less amounts charged to direct and indirect costs above ($394,361 in 1972 and $235,858 in 1971) (Note D)	263,228	263,228
Miscellaneous	205,494	187,134
Transfers to (from) working capital and contingency reserve	165,414	(57,099)
	$17,316,474	$14,527,096
Resources Used to Meet Operating Expenses:		
Income for sponsored research:		
For direct costs	14,149,572	11,904,983
For indirect costs	1,738,885	1,451,445
Fees for use of facilities	174,895	221,865
	16,063,352	13,578,293
Revenue from educational operations:		
Grants expended for fellowships	99,755	123,512
Gifts availed of	535,698	339,998
Tuition and rental income	151,495	125,431
	786,948	588,941
Unrestricted endowment income availed of (Note B)	286,694	172,282
Development program contributions for unrestricted purposes	80,787	128,088
Miscellaneous	98,693	59,492
	$17,316,474	$14,527,096

The accompanying notes are an integral part of the financial statements.

Statement of Changes in Funds

year ended December 31, 1972

	Endowment Funds (Note A)	Invested in Plant	Unexpended Plant Funds	Unexpended Balances of Restricted Gifts and Grants	Reserves: Income and Salary Stabilization	Reserves: Working Capital and Contingency
Balance at beginning of year	$21,182,615	$10,997,356	$1,454,157	$ 389,789	$1,164,991	$ 85,444
Restricted gifts and private and public grants received	12,900		1,246,589	8,280,161		
Restricted endowment income including investment gains of $46,684 availed of (Note B)	(46,684)			443,152		
Net gain on sales of investments	5,592,954					
Transferred to working capital and contingency reserve						165,414
Provision for depreciation (Note D)		(657,589)	394,361			263,228
Net book value of asset sold		(40,000)	40,000			
Availed of for research and education costs				(8,549,091)		
Transferred from working capital and contingency reserve to unexpended plant funds and income and salary stabilization reserve			391,129		95,565	(486,694)
Transferred from restricted gifts and grants to endowment funds	3,476			(3,476)		
Invested in plant		1,099,041	(1,099,041)			
Balance at end of year	$26,745,261	$11,398,808	$2,427,195	$ 560,535	1,260,556	27,392
						1,260,556
						$1,287,948

The accompanying notes are an integral part of the financial statements.

Schedule A

Summary of Endowment Assets

as at December 31, 1972

	Book Amount	% of Total	Market Quotation	% of Total
SEPARATELY INVESTED (FUNDS RESTRICTED AS TO PRINCIPAL AND INCOME):				
BONDS	$ 2,195,624	15.3	$ 2,188,000	9.0
COMMON STOCKS**	12,085,371	84.3	22,195,730	90.8
CASH	60,159	.4	60,159	.2
TOTAL	14,341,154	100.0	24,443,889	100.0
POOLED INVESTMENTS:				
BONDS	5,942,482	47.8	5,742,425	40.2
COMMON AND PREFERRED STOCKS**	6,132,268	49.3	8,169,047	57.2
REAL ESTATE	52,440	.4	52,440*	.4
CASH	303,139	2.4	303,139	2.1
OTHER ASSETS	11,038	.1	11,038*	.1
TOTAL	12,441,367	100.0	14,278,089	100.0
ENDOWMENT FUNDS DUE TO CURRENT FUNDS	(37,260)		(37,260)	
TOTAL ENDOWMENT ASSETS	$26,745,261		$38,684,718	

*At book amount.
**See Note A to the financial statements.

Notes to Financial Statements

A. Endowment fund assets include securities which are restricted as to public sale. Such securities were valued for book purposes at the market valuation of unrestricted securities of the same class, on the dates of gifts. The book value of these restricted securities amounted to $5,750,649 at December 31, 1972 ($9,140,400 at December 31, 1971).

Endowment fund assets also include securities for which a readily determinable market value cannot be established. Such securities are included at a nominal value of $1, in accordance with the existing policy of the Institution.

The changes in the market value of endowment fund assets were as follows:

	1972	1971
Market value beginning of year	$32,150,574	$19,211,923
Net gain in investment market value:		
Unrealized	971,498	7,842,091
Realized	5,592,954	689,890
Less investment gains availed of for restricted purposes	(46,684)	(28,824)
	6,517,768	8,503,157
Gifts	12,900	4,420,494
Transfers	3,476	15,000
	$38,684,718	$32,150,574

B. The Institution maintains a pooled investment account for all endowment funds except for funds restricted as to principal and income which are separately invested. Current year income of the pooled investments is distributed on the unit method as follows:

a. actual income earned to funds unrestricted as to income.

b. at a fixed annual rate (5% of a three-year moving average of the unit value of the Fund) to funds unrestricted as to principal, restricted as to income. The annual income distribution to these funds will be provided first from the current investment income of the fund and then from the gains on investments. The Institution's investment policy is to maximize the endowment fund's long-term total return (any combination of interest, dividends and capital appreciation).

Current year income on the separately invested securities of funds restricted as to principal and income is distributed directly to the funds to support the purpose of the donation.

Total endowment income, including investment gains of $46,684 availed of for restricted purposes in 1972, was allocated as follows:

	1972	1971
To meet operating expenses and in 1971, a transfer of $86,141 to the income and salary stabilization reserve	$286,694	$258,423
To restricted gifts and grants accounts	443,152	192,730
	$729,846	$451,153

C. Title to the Atlantis II is contingent upon its continued use for oceanographic research.

D. Depreciation is provided at annual rates of 2% to 5% on buildings, 3⅓% on Atlantis II and 5% to 33⅓% on equipment. Depreciation expense totaling $657,589 in 1972 and $499,086 in 1971 includes $263,228 in each year of depreciation on Atlantis II, Laboratory for Marine Science and the dock facility which is not charged to the costs of research activity or educational operations.

E. For its noncontributory retirement plan, the Institution charged $633,892 and $558,909 to operating expenses in 1972 and 1971, respectively. Under the terms of the retirement trust, the amount of the Institution's annual contribution shall be 12% of compensation paid by the Institution to plan members during the year.

F. Under contracts executed in connection with the construction of an educational facility and environmental systems laboratory, the Institution is committed to spend approximately $6,000,000 during the next two years.