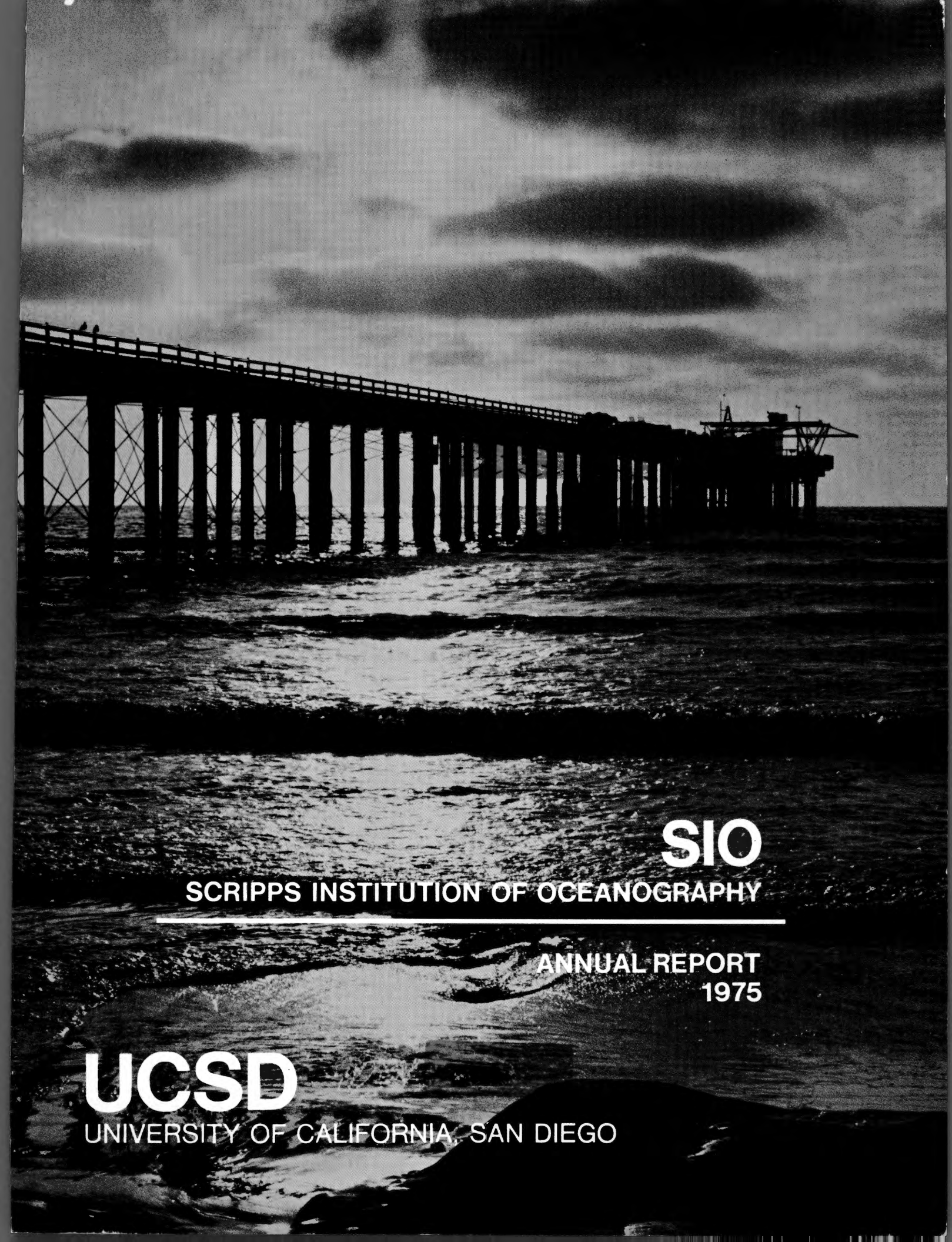

SIO

SCRIPPS INSTITUTION OF OCEANOGRAPHY

ANNUAL REPORT
1975

UCSD

UNIVERSITY OF CALIFORNIA, SAN DIEGO

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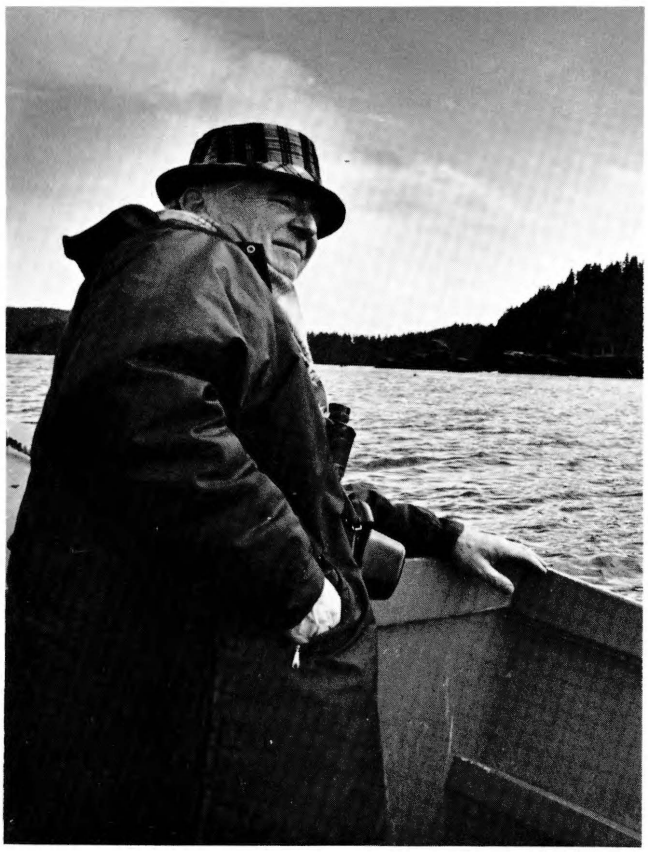
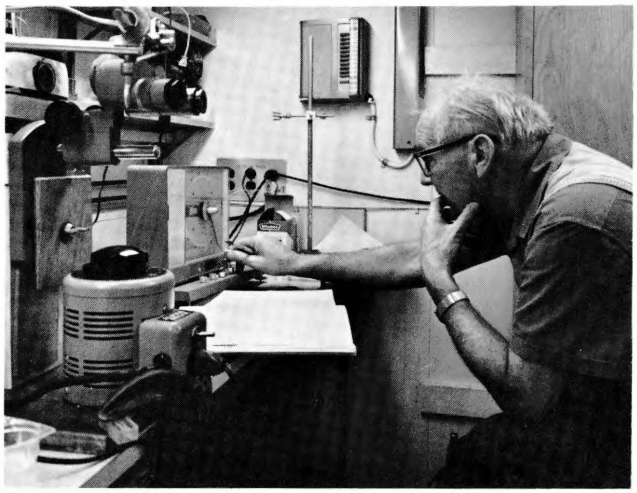




Aboard R/V Alpha Helix, *"Pete" Scholander huddles against chill air off Afognak Island, east of Kodiak, Alaska, a contrast to his attire in the ship's laboratory and particularly so as, on another occasion – with water half up to his knees – he studiously checks sap tension in mangroves in a Miami, Florida, swamp.*

Mangrove photo by Dr. Edvard A. Hemmingsen

"When people talk about research in the ocean, they tend to forget something very basic: the ocean will yield not only fish and protein but knowledge as well. And this knowledge is not restricted to the ocean. To me, there is no difference between plants and animals anywhere if you are interested in systems. They all operate on the same basic parameters, but emphases are different and comparisons rewarding."[1]

Per F. Scholander
Professor of Physiology Emeritus

"Pete" Scholander's philosophy of systems comes as no surprise when his colleagues realize that his restless, inquiring research in comparative physiology spans almost four decades, with subjects ranging from icebergs and whales to molecules and single cells, from the tropics to the arctic and to the antarctic, and from the rise of sap in the tallest redwoods to the secretion of gases by fishes at the bottom of the sea.

The plant studies in collaboration with his Scripps colleague, Ted Hammel, led to demonstration and exact measurements of the negative sap pressure in all vascular plants, and in particular, mangroves, which strongly implicated solvent tension as basic to any understanding of colligative properties and magnetic experiments on model systems. This view was verified by gravitational and magnetic experiments on model systems.

The discoveries of this peripatetic scientist include the regulation of blood circulation in diving mammals and birds, the remarkable capability of blood hemoglobin to facilitate movement of oxygen in body tissues, and the experimental verification of negative tissue-fluid pressure in animals, and its dynamics.

Dr. Scholander is Swedish-born and Norwegian-educated (his doctor of medicine degree is from the University of Oslo). His interest in botany led to studies of lichens of northern Greenland and Spitsbergen and to a doctorate in botany. Then followed service as an arctic and aviation physiologist with the U.S. Air Force, his naturalization as a U.S. citizen, research with climate adaptation in arctic and tropical animals, and several years at Harvard Medical School and Woods Hole Oceanographic Institution.

Back at his *alma mater* in Oslo, he conducted studies on climate adaptation in the Norwegian mountains, and led an expedition to Australia to investigate the aborigines, whose ability to live naked in freezing winter climate caused so much comment.

Then, finally, to Scripps in 1959, to head up the institution's Physiological Research Laboratory as its first director. He successfully generated a National Science Foundation grant to build not only the laboratory structure and adjacent testing pools but also the research vessel, *Alpha Helix*. This unique ship was dedicated in 1966 as a national facility for experimental biology, with strong emphasis on international cooperation in what "Pete" calls "tortuous times." The vessel left Nimitz Marine Facility in March 1966 for Australia on her first expedition, Billabong. Since then she has logged some 36 cruises resulting in 323 scientific publications and several hundred field reports.

Small wonder, then, that his cup ran over when his active career was capped with election in 1974 to the prestigious Swedish Royal Academy of Sciences. Truly, the ocean has yielded "Pete" Scholander much knowledge; he would have it no other way.

[1]Daniel Behrman, *The New World of the Oceans*, p. 24.

A delegation of some 25 American and Japanese officials was on campus in June to arrange for the October 9 visit to the institution of His Majesty, the Emperor of Japan. Stopping briefly on Scripps Pier were, from left, Mr. Keiichi Tachibana, Japanese Consul General, Los Angeles; Deputy Director Charles J. Merdinger; His Excellency, Mr. Hiroshi Uchida, Ambassador, Chief of Protocol, Ministry of Foreign Affairs; Mr. Yoshihiro Tokugawa, Vice-Grand Chamberlain to His Majesty; His Excellency, Mr. Morio Yukawaw, Grand Master of Ceremonies to His Majesty; and Director William A. Nierenberg.

INTRODUCTION

The year 1974-75 was indeed a different period for Scripps Institution. Construction continued on schedule for the new Marine Biology Research and Instruction Building. The NORPAX/Physical Oceanography Building was begun and completed during the year, and ground breaking for the new library took place. This represented the greatest building activity on the Scripps campus since UC San Diego started its construction program some 15 years ago.

A parallel effort on the Scripps fleet was initiated. R/V *Thomas Washington* was chosen to be the platform for a major, multichannel, seismic reflection system. The resources have been assembled, the planning completed, and their acquisition and installation are under way.

The Vaughan Aquarium-Museum continues to flourish. An exciting development was the delivery for public display of a coelacanth from the Comoros. Since it had been frozen alive after capture and was in excellent shape, a few tissue and body-fluid samples were taken for a number of biological and medical researches. The museum also developed an onshore tide-pool exhibit, complete with minitides and minicurrents, thanks to private donations. The display not only has educational value, but also diminishes visitation pressure on the local tide pools.

The report lists many honors and elections to honorary societies. Most interesting, in a way, is the election of Professor Devendra Lal as a Foreign Associate of the U.S. National Academy of Sciences. Thus, the institution now has 15 members of the academy, a record we can all be proud of. Of equal importance was the election of Professors Gustav Arrhenius and Per Scholander to membership in the prestigious Swedish Royal Academy of Sciences.

We also note the retirement of four long-time members of the institution. They are Drs. Theodore Folsom and Russell Raitt, Professor Victor Vacquier, and James Snodgrass. Each is a major innovator and contributor in a different field of oceanography. Together, they continue to be active, and are in the best position to observe and enjoy the establishment they helped build.

William A. Nierenberg

William A. Nierenberg, Director
Scripps Institution of Oceanography

R/V *George Melville*

R/V *Oconostota*

SEAGOING OPERATIONS

Nimitz Marine Facility and the Fleet

During fiscal 1974-1975, Scripps Institution operated seven research vessels, a utility cabin cruiser, and two research platforms. These included R/Vs *George Melville, Thomas Washington, Alexander Agassiz, Alpha Helix, Oconostota, Ellen B. Scripps,* and *Dolphin,* and R/Ps FLIP and ORB. *Melville, Thomas Washington, Alpha Helix,* and *Alexander Agassiz* were engaged in major expeditions. The fleet spent a total of 1,467 days at sea and traveled 163,237 nautical miles.

R/V *Melville* conducted sea trials and cruise preparations from August 19-23, 1974, and departed San Diego on Cocotow Expedition August 26, the first of five legs involving Deep-Tow geological studies, heat flow, and dredging and coring of the eastern Pacific and the Galápagos Islands area. She returned to San Diego December 18, and again departed San Diego January 20, 1975, on the first leg of six of the FDrake Expedition. The main emphasis was on Leg II, 42 days in the Drake Passage from Cape Horn to the South Shetland Islands, setting long- and short-term current meters and recovering the short-term instruments. The remaining legs involved dredging, coring, and surveying of the Peru Trench and Rivera Fracture Zone, and retrieving and redeploying bottom seismometers with biological tows at strategic points. *Melville* returned to San Diego June 12; on June 19 she made a one-day cruise with National Science Foundation and University of California officials. She spent a total of 262 days at sea and logged 34,858 nautical miles.

R/V *Thomas Washington* began fiscal 1975 engaged in Siqueiros Expedition operations in the eastern Pacific, doing primarily seismic reflection and refraction work and dredging. She returned from the expedition to San Diego on July 20. *Washington* departed again on September 19, commencing the first of 11 legs of Eurydice Expedition. Expedition work included seismic refraction and reflection, coring, dredging, heat-flow determination, bottom photography, and biological studies. *Washington* continued with the expedition into the new fiscal year; she logged 51,439 nautical miles in 282 days at sea.

R/V *Alexander Agassiz* opened the year at sea on Krill Expedition to Mexico, Peru, and Chile, for studies involving plankton, hydrography, nutrient chemistry, dredging, coring, and sediment analysis, and returned to San Diego September 12. On October 1, the ship departed for work on two CalCOFI (California Cooperative Oceanic Fisheries Investigations) cruises from San Francisco to the Gulf of California, conducting physical oceanography and fisheries work, and returning December 12. The year 1975 opened on January 20, with a Marine Life Research cruise, followed by shipyard overhaul and a series of short cruises involving a variety of seismic studies, biological sampling, and light-meter and deep-current studies. *Agassiz* logged 27,049 nautical miles and 196 days at sea.

R/V *Alpha Helix* was operating in the Bering Sea and Aleutian Trench areas on July 1, 1974, conducting biological and productivity studies, mammal research in Bristol Bay, and salmon and pelagic bird studies en route to San Diego, where she arrived September 29. *Alpha Helix* then visited the Gulf of California before departing San Diego January 27, 1975, to begin Cross Pac Expedition to Australia, Indonesia, and the Philippines, where she was working as of June 30, 1975. R/V *Alpha Helix* logged 25,115 nautical miles in 202 days.

R/V *Oconostota* left July 13, 1974, for the Gulf of California, where she was engaged in biological trawling, hydro casts, dredging, and field work on Tortuga Island, returning to San Diego August 1, 1974. For the next two months she conducted coring, bathymetry, Nansen casts, and trawling operations in local waters. On September 22, she worked with R/P ORB for the last time, and went into lay-up status awaiting delivery to San Jose State University, into whose custody she had been transferred for service out of Moss Landing, California. The vessel departed Nimitz Marine Facility for Monterey, California, August 16, 1975, thus ending an active period of utilization by the institution that began in 1962, when she was acquired from the U.S. Navy. R/V *Oconostota* logged 4,509 nautical miles in 44 days.

R/V *Ellen B. Scripps* accomplished 48 trips during the year, involving launching, tracking, and retrieving deep-sea capsules; intensity studies of electromagnetic forces in local waters; seismic refraction work; testing

R/V *Dolphin*

R/V *Alpha Helix*

R/P FLIP

R/P ORB

various types of hydrographic equipment, including free-fall instruments and releases; air-sea interaction studies; microstructure evaluation; submarine-canyon studies; and environmental studies; in addition to towing R/P ORB. The ship logged 11,183 nautical miles in 87 days.

R/V *Dolphin* conducted numerous operations in local waters including chemical and biological studies off San Onofre Nuclear Power Plant and recovery of free-falling vehicles. On January 6, 1975, she departed San Diego for the Gulf of California for seismic studies, whale studies, marine life collecting, biological and chemical studies of marine algae, and microbiological investigations. She returned April 24, and for the remainder was involved in deployment of acoustic-release mechanisms and the recovery of sediment recorders. She closed the year with a cruise to Guadalupe Island to observe the endangered fur seal. The ship logged 7,174 nautical miles in 103 days at sea during the year.

R/P FLIP, operating off San Diego, tested a Doppler-flow acoustic system; measured acoustic-propagation and ambient-noise characteristics; and tested other related equipment. FLIP spent 63 days at sea and was towed 1,858 nautical miles.

R/P ORB was engaged off San Diego in experiments with a remotely controlled, underwater vehicle (RUM), and acoustic arrays, and in testing and developing other instruments. ORB spent 38 days offshore and was towed 52 nautical miles.

FDrake Expedition

R/V *Melville* participated in FDrake Expedition to the tip of South America the first three months of 1975, as noted above.

The three-nation, three-ship, multiinstitution investigation in the vicinity of Cape Horn launched the first major field program of the International Southern Ocean Study (ISOS), which was sponsored by the National Science Foundation as a U.S. contribution to the International Decade of Ocean Exploration (IDOE).

Data recorded during FDrake in man's attempt to comprehend the oceanography of the Antarctic Circumpolar Current System have implications for understanding climate, ISOS scientists said. A second, concentrated study of the region is scheduled for early 1976.

"FDRAKE — or *F*irst *D*ynamic *R*esponse *a*nd *K*inematic *E*xperiment — marked a significant contribution to man's growing knowledge of oceanographic conditions in the Drake Passage and the Scotia Sea," according to John M. Morrison, Texas A&M University (TAMU) oceanographer and executive assistant in the ISOS program.

"By monitoring both the sea and the atmosphere, ISOS scientists hope to estimate the effect of surface wind on antarctic oceans and to determine how such effects contribute to changes in worldwide climate."

(In 1969, during Scripps's Piquero Expedition, five current-meter measurements were made within the Antarctic Cirumpolar Current System. Chief scientists Joseph L. Reid, of Scripps, and Worth Nowlin — now professor of oceanography at TAMU — then estimated the total amount of water flowing eastward from the Pacific into the Atlantic through the Drake Passage at approximately 270,000,000 tons per second. They indicated these figures were about twice the values estimated previously without benefit of current-meter measurements.)

Morrison reported that data from the first ISOS studies were taken with an array of 15 moorings that consisted of 43 current meters, 27 of which had temperature sensors, and four tide gauges stretching in a row some 724 km long between Cape Horn and Palmer Peninsula.

The array was installed by a team from Oregon State University (OSU) led by Dr. R. Dale Pillsbury. Eight of the moorings were left in the Drake Passage to accumulate more extensive information until they are retrieved in the 1976 operations.

The initial ISOS studies also included investigations of the Polar Frontal Zone within the Antarctic Circumpolar Current System.

The scientific party aboard *Melville,* with Dr. Nowlin as chief scientist, were from TAMU, OSU, Scripps, Argentina, and the Chilean Naval Hydrographic Institute.

The other ships working with *Melville* were ARA *Islas Orcadas* (formerly USS *Eltanin*), operated by the Argentine Naval Hydrographic Service, and R/V *Conrad* of Lamont-Doherty Geological Observatory, Columbia University.

En route from San Diego to Ushuaia, Argentina, the world's southern-

R/V *Ellen B. Scripps*

R/V *Alexander Agassiz*

Cabin Cruiser *Gianna*

R/V *Thomas Washington*

most port and departure point for the ISOS work, *Melville* made closely spaced observations of the thermal structure across the Equatorial Current System for study by Dr. David Halpern of the National Oceanic and Atmospheric Administration's Pacific Environmental Marine Laboratory in Seattle, Washington.

During *Melville's* return from Argentina to San Diego, she operated off northern Chile and Peru, the scientific party including participants from the United States, Chile, and Peru. OSU graduate student David Prince conducted a geological-geochemical program that continued a cooperative OSU-University of Hawaii-Scripps project also sponsored by IDOE.

Between Panama and San Diego, Dr. Michael Reichle of Scripps had been scheduled to retrieve by acoustic command three "pop-up" bottom seismometers placed earlier on the sea floor at points on the Rivera Fracture Zone, off the tip of Baja California. These capsules were designed to monitor earthquake activity in that area.

A malfunction prevented the instruments from responding to commands, however, and, at end of fiscal 1974-1975, they still remained in place pending plans to recover them.

Meanwhile, core samples were taken in the deepest points of the Rivera Fracture Zone, as were seismic reflection records, the first of such extensive data taken in that region.

R/V *Melville,* which departed San Diego January 20 for the Drake Passage operations, logged an estimated 20,000 underway nautical miles before returning to San Diego on June 12. Master of the ship for the entire cruise was Capt. Alan W. Phinney.

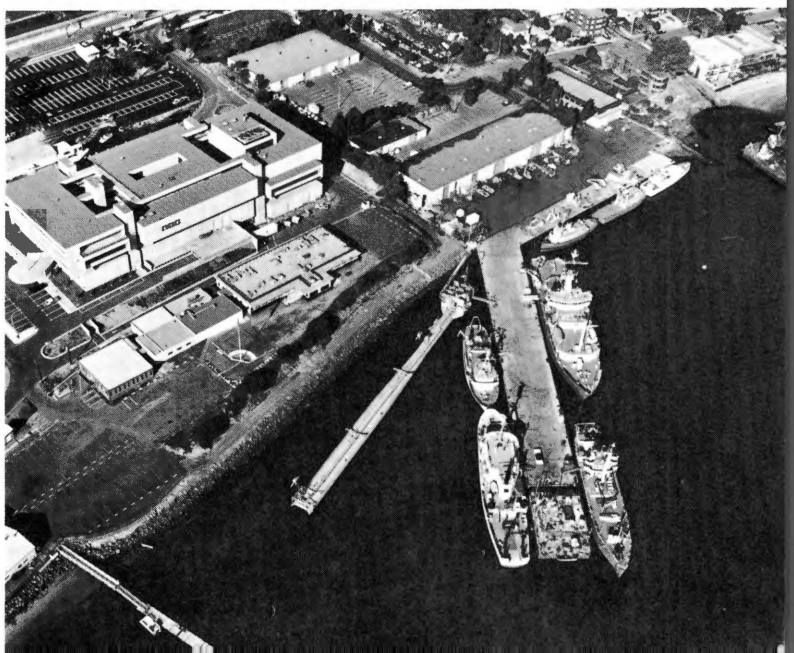
Keith Jackson, 19, University of North Carolina student who rode his bicycle from Alaska to tip of South America, stretches his legs after arriving at Nimitz Marine Facility aboard R/V Thomas Washington, *upon which he signed as deckhand in Tierra del Fuego, where his 28,968-km trip ended.*

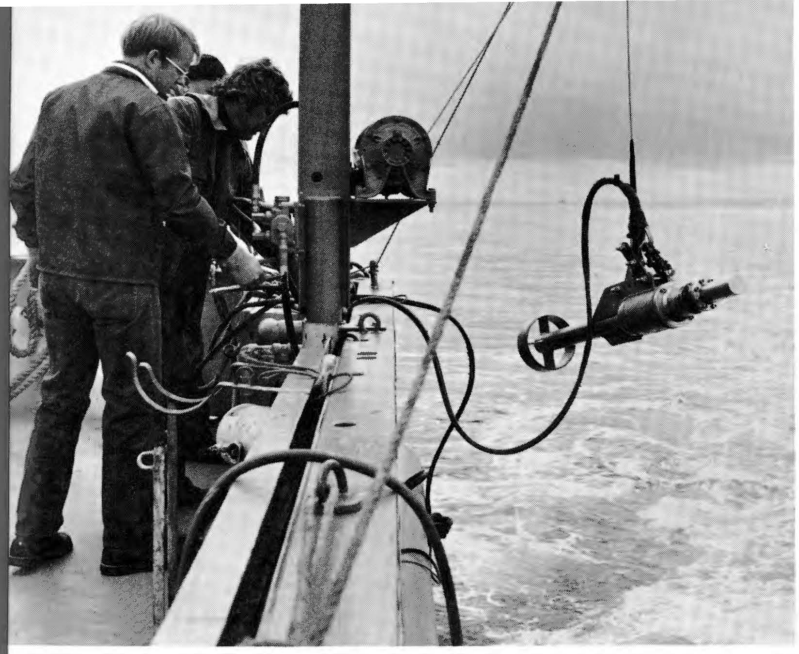
Photo by Dan Tichonchuk, courtesy of San Diego Evening Tribune

Aerial photograph of the institution's $2-million Nimitz Marine Facility, right of center, on the San Diego Bay-side of Pt. Loma, taken in December 1974, when all but one of Scripps's research vessels and both platforms were in home port. Left of center, and adjacent to Nimitz, are Naval Undersea Center (NUC) facilities. Scripps's concrete pier and marginal wharf extension, upper right from pier, accommodate all of Scripps's fleet of six research ships and two research platforms, FLIP (Floating Instrument Platform) and ORB (Oceanographic Research Buoy), and the National Marine Fisheries Service's R/V David Starr Jordan. *From right to left along wharf and clockwise around pier are R/Vs* Dolphin, E. B. Scripps, Oconostota, Melville, *and* Agassiz, *and R/P ORB, rectangular object at end of pier; R/Vs* Jordan *and* Alpha Helix, *and R/P FLIP, extending from land end of pier into center foreground. Scripps's second largest research vessel,* Thomas Washington, *was on an expedition to the western Pacific.*

Assistant Director Jeffery D. Frautschy, at left, presents painting to James L. Faughn, veteran seagoing captain, on occasion of his retirement after 27 years' service to the institution. Painting is a watercolor by George M. Mattson, artist, formerly with the National Marine Fisheries Service in La Jolla, and was a gift from Faughn's friends at Scripps.

Norman J. Sattler





Highlight of National Science Board (NSB) meeting held on campus in June was a trip to sea on R/V Melville *to observe shipboard demonstrations of research activities. At lower left, Director Nierenberg, at left, discusses operations of air gun, center, used in seismic profiling, with UC San Diego Chancellor William D. McElroy and, at right, NSB Chairman Norman Hackerman, Rice University president. At lower right, Associate Director Fisher gesticulates in conversation with, second from left, National Science Foundation Deputy Director Richard D. Atkinson and daughter Lynn, as Deputy Director Merdinger listens in. At top left, Robert C. Wilson, foreground, and Perry J. S. Crampton deploy air gun, aided, in background, by Jery B. Graham. At left, Wilson gives "go slow" signal to winch operator as he and Crampton bring up salinity-temperature-depth (STD) instrument. At top right, George C. Anderson streams neuston tow net to gather plankton samples usually found within half a meter of ocean surface.*

GRADUATE DEPARTMENT

Graduate education at the Scripps Institution and its predecessors can be traced back to before the time the institution became a part of the University of California in 1912. Graduate degrees based on work done primarily at Scripps were awarded by UC-Berkeley and UC-Los Angeles until 1961, when UCSD became a degree-granting campus of the university.

In the early days of UCSD, graduate education was administered through the three departments at Scripps: oceanography, marine biology, and earth sciences. In 1967, these departments were merged into the present Graduate Department of the Scripps Institution of Oceanography. Curricular programs are offered within this department in applied ocean sciences, biological oceanography, geophysics, marine biology, marine chemistry, geological sciences, and physical oceanography. Each curricular group has some of its own special requirements for admission (in addition to those applying to the department as a whole) and some of the department's course requirements and policies.

Growth is often most vigorous in the rapid evolution of modern marine sciences at the boundaries of established disciplines, so that the interests of a given student, like those of many of the faculty, may fall somewhere between the limits of the curricular programs. It is the intent of the Scripps Graduate Department to provide maximum flexibility in meeting the specific interests of individual students.

The Graduate Department is chaired by Dr. Joseph R. Curray, professor of marine geology. Dr. Michael M. Mullin, associate professor of oceanography, is vice-chairman. The department includes about 60 regular faculty members and four adjunct professors from the National Marine Fisheries Service. In addition, 12 members of the professional research staff voluntarily serve as lecturers in the department.

GRADUATE CURRICULAR PROGRAM. Each graduate student selects one of the seven curricular programs, which are described below with the name of the faculty curricular-group coordinator. The Scripps Institution is largely a research institution. An important part of the educational program is the individual participation of each graduate student in some aspect of the research programs described elsewhere in this report.

Applied Ocean Sciences (Dr. Clinton D. Winant). This curriculum is concerned with man's purposeful and useful intervention into the sea. Interdepartmental in nature, it combines the resources of the Graduate Department of Scripps and two engineering departments on the San Diego campus of the university: the Department of Applied Mechanics and Engineering Sciences and the Department of Applied Physics and Information Science. An attempt is made to produce modern engineers with a substantial training in oceanography and oceanographers with a significant ability in modern engineering. Instruction and research include structural, mechanical, material, electrical, and physiological problems operating within the ocean and the applied environmental science of the sea as well. Since physical, chemical, geological, and biological aspects of the oceans and all forms of engineering may be involved, the curriculum provides maximum flexibility in meeting the needs of each individual student.

Biological Oceanography (Dr. Robert R. Hessler). Biological oceanographers are concerned with the interactions of populations of marine organisms with one another and with their physical-chemical environment. Research and education activities in this curriculum include studies of the factors influencing primary and secondary productivity and nutrient regeneration, food-chain dynamics, community ecology of benthic and pelagic forms, population dynamics, fisheries biology, taxonomy and zoogeography of oceanic organisms, and behavior as it affects distribution and sampling problems.

Geophysics (Dr. Robert L. Parker). This curriculum is designed to develop the ability of the physicist (theoretician or experimentalist) to contribute to man's understanding of the sea, the solid earth on which it moves, and the atmosphere with which it interacts. The program initially assists the student in assimilating current knowledge of the nature of the earth and in gaining mastery of field, laboratory, and mathematical techniques by which new information is being developed. With this basic background, the student is then expected to take part in the development of new insight into the problems of the structure of the earth and the nature of energy propagation and exchanges which take place within it.

Marine Biology (Dr. Ralph A. Lewin). This curriculum is concerned with the study of the development, adaptation, and function of organisms in the marine environment. The comparative physiology, biochemistry, and developmental biology of marine organisms are stressed in course work. Students specializing in subjects from neurophysiology to barobiology will find breadth of interest and intensity and sophistication of the experimental approach as adapted to conventional marine technology.

Marine Chemistry (Dr. Gustaf Arrhenius). Marine chemists are concerned with chemical processes operating within the marine environment: the oceans, the marine atmosphere, and the sea floor. The interactions of the components of seawater with the atmosphere, with sedimentary solid phases, and with plants and animals form the bases for research programs. These include investigations of the carbon system, natural products, chemical interaction between marine organisms, physical and inorganic chemistry of sediment-water systems, organic chemistry in the marine environment, distribution of noble gases in seawater, and effects of pollutants on the marine environment.

Geological Sciences (Dr. Edward L. Winterer). This curriculum emphasizes the application of observational, experimental, and theoretical methods of the basic sciences to the understanding of the solid earth and solar system and their relationship to the ocean and atmosphere. Principal subprograms at Scripps are marine geology, tectonics, sedimentology, micropaleontology, petrology, and geochemistry. Expedition work at sea and field work on land are emphasized as an essential complement to laboratory and theoretical studies.

Physical Oceanography (Dr. Robert S. Arthur). Studies in physical oceanography include the observation, analysis, and theoretical interpretation of the general circulation of ocean currents; the distribution and variation of properties of the ocean; the interchange of kinetic and thermal energy and materials across the ocean surface; the propagation of sound and light and other electromagnetic energy in the ocean; and the properties and propagation of ocean waves.

GRADUATE STUDENTS AND DEGREE RECIPIENTS. In the fall of 1974, 40 new students were admitted to graduate study. Of these, 6 were in marine biology, 13 in geological sciences, 6 in marine chemistry, 4 in biological oceanography, 4 in physical oceanography, 3 in geophysics, and 4 in applied ocean sciences. Fifteen were California residents, 18 were from out of state, and 7 were from foreign countries. Enrollment at the start of the 1974 school year totaled 186 students.

During the academic year 1974-75, 12 Master of Science degrees and 35 Doctor of Philosophy degrees were awarded by UCSD to students having completed advanced studies at Scripps. This is the largest number of degrees ever awarded in a single year by the institution. The names of degree recipients and the titles of doctoral dissertations are listed in Appendix E.

RESEARCH ACTIVITIES

Deep Sea Drilling Project

Fiscal 1975 was one of particular significance to the Deep Sea Drilling Project, managed by Scripps Institution under contract to the National Science Foundation. Aside from the several important scientific accomplishments, final steps were taken to prepare for the International Phase of Ocean Drilling which begins in the fall of 1975. In keeping with the project's increased tempo of international involvement, Memoranda of Agreement, calling for financial participation, neared completion between the National Science Foundation, representing the United States, and representatives of the Japanese*, French, and British governments. These are in addition to Russia and West Germany, which have been participating members since January 1, 1974.

During the reporting period, the DSDP drilling ship *Glomar Challenger* traveled more than 57,000 km in carrying scientists — about half of whom were from foreign nations — from the Norwegian Sea to the South Atlantic, then northward along the coast of Africa, and into the Mediterranean and Black seas. In that time, 68 holes were drilled into the sea floor, and more than 1,600 cores were recovered. Global Marine Inc., of Los Angeles, operates *Glomar Challenger* under contract to Scripps.

*The Japanese Agreement was finalized on July 18, 1975, in Tokyo.

Three members of the scientific team aboard D/V Glomar Challenger *during Leg 42A of the Deep Sea Drilling Project in the Mediterranean Sea discuss the structures in sediment drilled and cored during the cruise. Left to right, Dr. Daniel Bernoulli, sedimentologist, from Geologisch-paläontologisches Institut der Universität Basel, Basel, Switzerland; Dr. Maria Cita, paleontologist/foraminifera from Instituto di Paleontologia, Università degli Studi di Milano, Milano, Italy; and Co-chief Scientist Dr. Ken J. Hsu from Geologisches Institut, ETH, Zurich, Switzerland, enjoy a coffee "break" while studying and discussing the recovered sediment.*

One of the noteworthy achievements occurred early during Leg 37. Record deep drilling beneath the floor of the Atlantic Ocean at a point west of the Azores yielded new information about formation of the earth's crust, and demonstrated that very deep penetration of the hard rocks of the deep sea floor is now within reach.

Examination of the cores shows that the upper part of the volcanic oceanic layer is composed of submarine basalt flows interlayered with deep-sea sediments. The relative abundance of sediment decreases with depth until only volcanic rocks are encountered. This volcanic-sedimentary sequence probably formed on the floor of what was the median valley of the Mid-Atlantic Ridge some 3.5 million years ago. The accumulation occurred over a period of 100,000-200,000 years. New crust formed during cycles of massive eruptions. There were periodic decreases in activity permitting deep-sea sediments to collect on top of the lava flows between eruptions. A number of repetitive volcanic cycles were identified in this sequence, and a few unique types of lava interrupted the cycles at odd intervals.

On Leg 38, significant new information regarding the evolution of the Norwegian and Greenland seas was revealed by DSDP scientists. Boring deep into the ocean floor in this remote stretch of sea lying between the North Atlantic and Arctic oceans, researchers made the observations based on preliminary shipboard analysis of sediment and hard-rock samples. Some of the samples are believed to contain the oldest oceanic rocks in the Norwegian Sea, dating back some 55 million years. Recovered cores also yielded information about the crumbling of the continental margins bordering the Norwegian and Greenland seas, the history of glaciation in the Northern Hemisphere, and the possible presence of oil in sediments in relatively deep water.

Of particular significance are those 55-million-year-old rocks. Now, the date at which the connection was lost between Eurasia and America by the breakup of the original supercontinent and the subsequent drifting away of Greenland from Norway can be fixed at 55 million years.

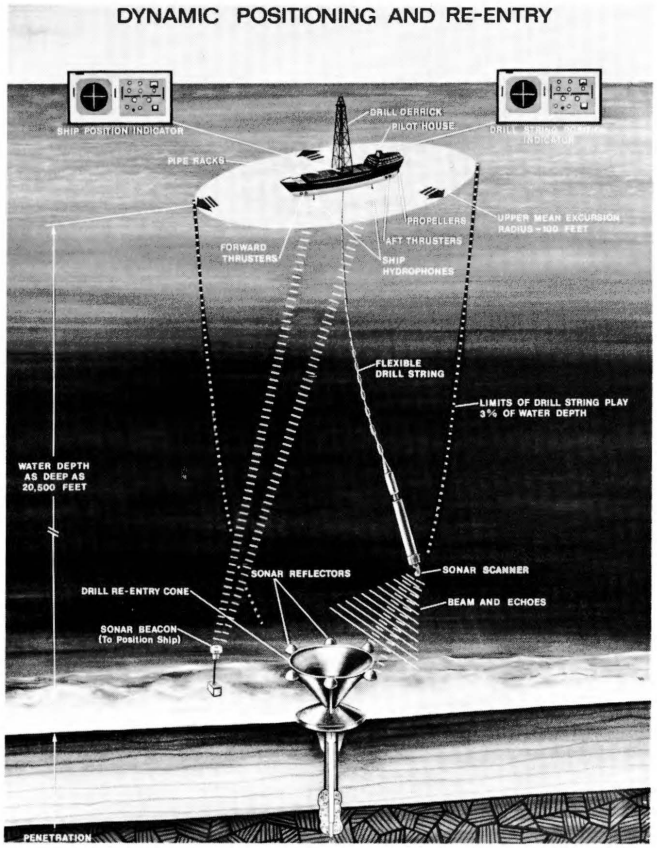
On the Norwegian side of the ocean, the oldest oceanic rocks form a mountain chain, now buried under sediment, that was originally several kilometers high and about 100 times as long. This chain served as a kind of bulwark behind which were thick deposits of sediments created by erosion from the Norwegian mainland.

Scientists further observed that the Norwegian Sea apparently did not open up in a continuous fashion but, rather, evolved in three distinct steps. During the first period of opening, the Norway Basin, a body of deep water off the Norwegian coastline, was created. By coring rocks from the center of this basin, scientists learned that the opening of this basin stopped about 30 million years ago. At about this same time, the line along which the opening was taking place shifted about 160 km to the west.

During the next phase, between 15 and 30 million years ago, further widening caused a piece of the Greenland coast to break off. This severed portion of Greenland ultimately subsided below the ocean surface to form a submarine plateau now known as the Jan Mayen Ridge. Also, the axis of opening moved again and now passes through Iceland. During the second shift, however, there appears to have been no breaking off from Greenland. From cores recovered later in Leg 38, scientists deduced that, for about 30 million years, the ridge that forms the southern boundary of the Norwegian Sea was above water much like present-day Iceland. Thus, the final land bridge between Eurasia and North America was not severed with the opening of the Norwegian Sea, but continued to exist until about 20 million years ago, when the ridge finally submerged. As it did so, the warmer Atlantic water moved into the Norwegian Sea and improved the otherwise frigid climate of Scandinavia and the eastern Arctic.

On Leg 39, scientists probing another sector of the Atlantic documented the birth of the Amazon River. While drilling the Ceara Rise, a subsea plateau 483 km off the coast of Brazil, investigators were able to determine the period of time in which the Amazon was formed. The lower-sediment cores from the Ceara Rise contained only fossil remains of tiny animals that lived and died in the ocean. Cores of early Miocene (24 million years ago) and younger, however, contained important evidence of land-derived material, minerals, and particles such as those being carried into the Atlantic Ocean by the Amazon River of today. Scientists also believe the Andes Mountains were formed during the early Miocene. It is therefore theorized that the formation of the great Andes range caused most of the heavy drainage of tropical South America to flow toward the Atlantic Ocean in an ever-growing stream that became the Amazon River.

Two "roughnecks" working for Global Marine Inc., transfer links from one set of drill-pipe elevators to another on the drill floor of D/V Glomar Challenger *during Leg 41 of the Deep Sea Drilling Project in the Atlantic Ocean. The dual elevator system is required because of the notch sensitivity of the high-strength drill pipe used by the project. This action must be taken every time a 27-m stand of the S-135 drill pipe is lowered or pulled out of the water.*



D/V Glomar Challenger *uses "dynamic positioning" to hold station above a sonar sound source placed on the ocean bottom while drilling. Two tunnel thrusters forward and two thrusters aft, along with the vessel's two main propellers, are computer controlled to hold position without anchors in water depths up to 6,100 m so that drilling and coring can be accomplished. When a drill bit is worn out, it is now possible to retract the drill string, change the bit, and return to the same bore hole through a reentry funnel placed on the ocean floor. High-resolution scanning sonar is used to locate the funnel and to guide the drill string over it. Operational reentry was first achieved by DSDP on Christmas Day 1970 during Leg 15 in the Caribbean Sea.*

The artist's concept shows a sonar beacon used for "dynamic positioning" and a sonar scanner at the end of the drill string searching for the three sonar reflectors on the reentry cone. The relative position of bit and funnel is displayed at the surface on a Drill String Position Indicator Scope. DSDP developed reentry when stopped short of scientific goals at many bore holes in the Atlantic and Pacific oceans. The bit would hit beds of chert or flint-like rocks that dulled the bit and forced early abandonment of bore holes.

Operating off the southeast coast of Africa during December 1974, and January 1975, Leg 40 scientists found evidence that the ancient Atlantic Ocean, instead of being a stable environment throughout its history, as previously thought, was subject to tremendous environmental stress, especially during its early formative stages. Its waters changed from fresh to brackish to saline and from oxygen-depleted to aerated; and, at one period, may have dried up completely.

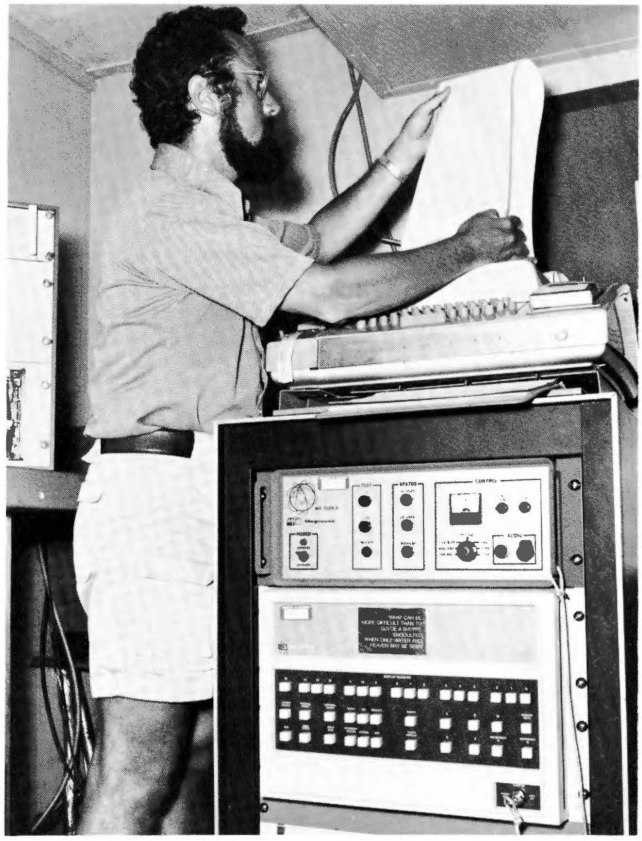
Initially brought into existence as a narrow crack, the South Atlantic was destined to widen continuously and eventually split Africa entirely away from South America. Identification in coastal basins of fossil remains of plants and animals that lived at that moment in history has indicated that the crack was first occupied by fresh waters of deep lakes similar to the present-day East African rift-valley lakes. Despite vast amounts of sand and mud pouring into the basins from the adjacent continent, the floor of the expanding lakes progressively deepened to a level more than 2 km below the edge of the bordering continental platforms. The character of the water also changed from fresh to saline as the rift broadened.

DSDP scientists presently theorize that the now-infant seaway was unable to supply sufficient oxygen to the deep waters because of sluggish circulation, and that a kind of suffocation developed and continued for more than 20 million years. Thousands of centimeters of organic-rich shale were laid down with interbeds of massive layers of sand washed down from the adjacent continents.

As the split between the continents extended northward, marine waters from the stagnant seaway seeped north across the already forming Walvis Ridge toward the equator. The rate of evaporation exceeded the rate of water input, and a massive layer, some 2,400 m thick, composed of evaporite minerals and rock salt, was deposited along the axis of the splitting crust. That entire body of salt, which stretches from the Walvis Ridge to Nigeria, was deposited in only a few million years. In other words, the still-youthful seaway practically filled itself with salt deposits in a brief instant of geologic time that lasted barely one percent of its present age. The mass of salt deposited is equivalent to about ten percent of all the dissolved salt in the rest of the world's oceans!

The period of salt deposition ended abruptly for unknown reasons as cool marine water of normal salinity and plankton species invaded the area from the south. Stagnation similar to that which occurred in the Cape Basin to the south developed, however, and lasted much longer in the north than it did in the south. This did not end, in fact, until the westward drift of South America slid the right-angled coastline of what is now Brazil totally clear of the bulge of West Africa.

Leg 41 scientists had to drill more than a kilometer below the floor of the ocean, passing through more than four km of water, to recover samples of sediments deposited during the early evolution of the Atlantic. During the process, scientists were able to sample almost continuously the overlying sediments and bring to light rock specimens that will help decipher, step by step, the history of the eastern North Atlantic. That story is recorded in layers of lime mud, clays, and sands that have accumulated slowly on the



Dr. Brian K. McKnight, of Wisconsin State University, a sedimentologist on Leg 40 of the Deep Sea Drilling Project, reads a satellite-navigation position print-out as D/V Glomar Challenger *nears desired location in the Cape Basin for Site 361. The cruise was from Capetown, South Africa, to Abidjan, Ivory Coast.*

Scientists from Austria and England examine deep-sea sediment core in repository at Deep Sea Drilling Project (DSDP) headquarters. Dr. Thomas A. Davies, DSDP staff coordinating geologist, center, describes sediment features to Dr. Peter Steinhauser, geophysics professor, Center for Meteorology and Geodynamics, Vienna, at left, and Dr. James Williamson, university lecturer in atmospheric physics, Oxford University, London. The two visitors were among group from abroad participating in annual IBM Professors Tour of scientific, educational, and governmental organizations in the United States.

During his visit to the institution. H. Tyler Marcy, Washington, D.C., at left, assistant secretary of the Navy for research and development, examines deep-sea sediment core described by Dr. Melvin N. A. Peterson, manager of Deep Sea Drilling Project.

sea floor. Embedded in this material are fossil remains of planktonic plants and animals of microscopic size that not only indicate the age of the sediments themselves, but also provide an indication of the environment in which they lived.

As a result, shipboard scientists found that the bottom of the young ocean and its nearby margin, covered with Jurassic limestones 150 million years old, foundered rapidly after the separation of America from Africa. Forty million years after the deposition of these limestones, the ocean was almost as deep as it is today.

Glomar Challenger returned to the Mediterranean Sea in April and May of 1975 to conduct a second drilling program. The international team of scientists, comprising Leg 42A, examined in more detail some of the extremely exciting, but controversial, findings of the first DSDP voyage to the Mediterranean in 1970 (Leg 13).

A major point of discussion after the 1970 cruise was whether deep basins had existed within the Mediterranean area prior to six million years ago. By employing recently developed drilling techniques, Leg 42A scientists probed deeper than on the first cruise into the sedimentary rocks below the evaporite deposits in the individual small basins that make up the present-day Mediterranean Sea. Results from this drilling effort proved that water-filled basins at least 500 to 1,000 m deep existed prior to the deposition of the salt, and that they have remained relatively unchanged in size to the present day. Furthermore, the work indicated that the onset of the "crisis of salinity" was a relatively sharp and catastrophic event in the western Mediterranean.

This drilling into older rocks also confirmed the previously held hypothesis that the eastern Mediterranean basins were formed more than 65 million years ago. Basins investigated in the western part of the sea were found to be considerably younger.

Following the Mediterranean expedition, Leg 42B centered in the Black Sea. As a result of preliminary analysis of cores recovered there, scientists expect the Black Sea to become a fresh-water lake once again when the next ice age arrives, an event which, according to some, may occur within 10,000 years.

Mission of Leg 42B was to investigate changes in the minerals and fossils buried in the sediment layers of the Black Sea as a key to understanding more about the geological processes that accompanied the ice ages of the past million years. These were times during which massive ice sheets extended down from the Arctic to cover large areas of what are today the developed and populated regions of Canada, northern Europe and the United States.

Three holes were drilled in the Black Sea, the deepest extending almost 1,000 m below the seabed. Study of the sediments indicates three major cool-dry periods, perhaps correlating with three of the four glacial stages recognized by land geological studies in Russia, western Europe, and the United States. The question of the fourth geological state is unresolved, and awaits further and more detailed study of the cores recovered on Leg 42B. In all, more than 75 percent of the sediments are of lake origin, indicating that the present sea level is atypically high considering the average of the last million years.

Geological Research Division

The research group of Dr. Gustaf Arrhenius is devoting work to problems associated with the removal of transition elements from seawater into the sediment, the secondary transport of these elements within the sediment, and their ultimate precipitation in the form of a number of discrete crystalline phases. These problems are related to formation of ferromanganese oxyhydroxide deposits (including manganese nodules), to the incorporation under some circumstances of comparatively large amounts of nickel, copper, and cobalt in some of the mineral phases, and to the unusual catalytic properties of these phases.

The present investigations attempt to clarify the site of substitution of copper and nickel in the transition element oxide crystals by studying their magnetic properties and crystal structure by electron diffraction. Another investigation related to the formation of manganese nodules is the work of Dr. Saara K. Asunmaa, UCSD, on possible mechanisms of catalytic oxidation of manganese on solid surfaces in seawater.

This past spring, Jimmy L. Greenslate finished his thesis studies on the associations of biota and manganese in the northeastern Equatorial Pacific sediments. This work included studies of the role played by organisms in the size range of .001-.1 cm in the development of manganese nodules.

Technological developments within this research group include new materials derived from ocean resources. Development of a lightweight, insulating, building material based on deep-ocean sediments has been

undertaken. This new ceramic material shows promise of utilizing an abundant resource with unique properties, obtainable as a by-product of deep-ocean mining. It offers higher compressional and flexural strength and lower thermal conductivity when compared to similar cellular concrete products currently in use. Efforts are being made to analyze and control the mechanisms that are responsible for bonding. The same processes appear to control the alteration with age of the siliceous-calcareous sediments on the sea floor.

Research within the group also includes the studies of Dr. Hannes Alfvén, of UCSD's Applied Physics and Information Science Department, and Dr. Arrhenius, on the origin and development of the solar system. This work is a systematic study endeavoring to apply to the study of cosmology new physical and chemical insights into the properties of matter in the space environment. Their book, *Evolution of the Solar System,* will be published by the National Aeronautics and Space Administration. From these studies derives work within the group on the processes that are responsible for the formation and evolution of the ocean, and on the differentiation of elements in the crust and mantle of the earth.

Instrumentation facilities of this group have been further refined to suit the particular needs for high-resolution analysis of composition and structure of solids. Ray W. Fitzgerald, Jane Z. Frazer, and Lawrence J. Glasser, in collaboration with Ronald T. La Borde, have also extensively contributed to the further development of the Scripps Analytical Facility.

The Scripps Sediment Data Bank, directed by Frazer, assisted by Donna L. Hawkins, Mary Fisk, and Glasser has added about 3,400 sediment descriptions and several hundred manganese-nodule analyses during the past year, mainly from the Indo-Pacific area; the total number of data points in the data bank now exceeds 46,000. Demand for output from Scripps students and staff and from industrial and governmental sources continues.

Computer programs for searching data files and mapping data from interactive remote terminals were completed. With the assistance of graduate student Michael C. Karas, a file for information about sea-floor photographs is being added to the data bank. Present work involves providing data to the U.S. Department of the Interior for its ocean-mining program and minerals availability system, and compiling sediment data for the International Decade of Ocean Exploration's Southeast Asia Project.

Dr. Wolfgang H. Berger and his associates, Drs. Peter H. Roth and Thomas C. Johnson, studied carbonate sedimentation on the Ontong-Java Plateau, east of New Guinea. It was learned that large-scale mass-waste processes on the flanks of the plateau are associated with depth-controlled dissolution processes (see accompanying figure). Several box cores taken on the plateau are being studied for postglacial climatic variations and for bioturbation. Work on the differential preservation of calcareous and siliceous microfossils continued in collaboration with Frances L. Parker, graduate student Charles G. Adelseck, and Drs. Roth and Johnson. The search for dissolution pulses and cycles has been extended to Miocene-age rocks by Dr. Edith S. Vincent. She also joins Dr. Berger and Drs. Edward L. Winterer and Jerry L. Matthews in exploring implications of such pulses and cycles for the acoustic stratigraphy of deep-sea carbonates. Dr. John S. Killingley is working on stable isotopes (oxygen and carbon) of deep-sea carbonates.

Dr. Harmon Craig's group continued to be occupied with the analysis of samples collected by the 1972-73 and 1973-74 GEOSECS expeditions in the Atlantic and Pacific, respectively.

In March and April, Dr. Craig, together with Valerie Craig, Fred S. Dixon, and Dr. Ray F. Weiss, conducted a second expedition on Lake Tanganyika, Africa, continuing studies initiated in the 1973 expedition. During the present expedition, Dr. Craig, V. Craig, and Dixon were captured by Zaire (Democratic Republic of the Congo), Africa, gunboats that towed their United Nations vessel to Zaire. The trio were held as prisoners overnight, then released the following day. A detailed study of the southern basin was made during the trip. Later Dr. Craig and V. Craig worked in Kenya studying the U.N.-developed, geothermal steam field at Naivasha, East Africa.

Two of Dr. Craig's students completed theses during the reporting period. Manuel E. Fiadeiro finished his doctoral thesis, "Numerical Modeling of Tracer Distributions in the Deep Pacific Ocean," which developed a three-dimensional numerical model for the Pacific. Michael D. Applequist completed his master's thesis, "Lead-210 in the Deep Sea: Pacific Ocean Investigations," a study of lead-210 distribution in particulate and dissolved form in the Pacific.

Other work by Dr. Craig included collection of volcanic gases at Kilauea Crater, Hawaii, and in Lassen Park. Drs. Craig and John E. Lupton learned that the helium in these gases is similar to the helium they studied previously in oceanic basalts; the He^3/He^4 ratio is ten times greater than atmospheric helium because it contains primordial helium from the mantle.

Dr. Yu-Chia Chung continued to study Ra^{226} distribution in the Pacific Ocean, based on samples collected from the GEOSECS Pacific Expedition in 1973-74. During the year four profiles were completed that revealed detailed structures presumably reflecting regional mixing and circulation of water masses. For example, in the central Pacific near Hawaii, where the Antarctic Bottom Water is spreading, a layered structure associated with a benthic front has been observed on radium and temperature profiles. More data are being accumulated to depict mixing and circulation patterns in the Pacific. Together with Applequist, Dr. Chung also studied the disequilibrium system of Ra^{226}-Pb^{210} in the Pacific deep and coastal waters.

Dr. Lupton has been employing a special He^3/He^4 mass spectrometer to study the distribution of helium isotopes in the oceans. Drs. Lupton and Craig are collaborating with Dr. Brian Clarke of McMaster University, Ontario, Canada, in the analysis of He^3/He^4, and neon in samples collected at 65 GEOSECS stations in the Atlantic and Pacific. Preliminary results at 13 GEOSECS Pacific sites have already made it possible to construct a general He^3/He^4 map of the Pacific. This map points strongly to the East Pacific Rise as the major source of the excess He^3 in the Pacific Deep Water. These oceanic He^3 measurements, combined with the previous discovery of excess He^3 in Pacific Ocean basalts, are strong evidence for the existence of an oceanic flux of "primordial" He^3 from the earth's interior injected during the formation of new oceanic crust. In addition to the problem of the terrestrial helium budget, helium isotopes are becoming extremely useful tracers for studying oceanic circulation. In the South Pacific, the boundary between the bottom water and the overlying deep water, the "benthic front," is clearly marked by a 10 percent difference in the He^3/He^4 ratio. An analogous boundary in the South Atlantic shows a 4 percent helium isotope variation. In the North Atlantic, the presence of bomb-produced tritium, which decays to He^3 with a 12-year half-life, has made it possible to study the short-term circulation by assigning H^3-He^3 "ages" to water samples.

Using a nondestructive method, Dr. B. L. K. Somayajulu, of the Physical Research Laboratory, Ahmedabad, India, and Thomas J. Walsh logged for magnetic-susceptibility stratigraphy about 100 gravity cores from the institution's core library. These measurements, made for the first time, show that studies of magnetic-susceptibility stratigraphy can be used to delineate prominent volcanic episodes in the past. Open-ocean and trench sediments show pronounced high magnetic-susceptibility regions. Efforts are being made (1) to make age correlations between "peaks" observed in different sediments and; (2) to extend such measurements to Deep Sea Drilling Project cores.

Research by Dr. Somayajulu and Dr. Devendra Lal, the latter also from the Physical Research Laboratory in Ahmedabad, once again demonstrated that particulate transport of surface carbon fixed in biological organisms constitutes an important mode for transfer of carbon to the deep sea. Samples of particulate inorganic carbon from the open ocean off San Diego and the Santa Barbara Basin contained appreciable amounts of recent carbon fixed in the euphotic zone as determined by the presence of man-made C^{14} activity. In the same particulate samples, bomb-produced Fe^{55} activity was also studied. The rate of vertical downward movement of Fe^{55} was found to be considerably lower than for C^{14}, indicating clearly that Fe^{55} activity attaches itself to small particles, whereas the former is incorporated in larger particles according to the marine biological complex. Settling rates for C^{14} and Fe^{55} are 1.5-2.0 and 0.4-0.5 m/day^{-1}, respectively.

Drs. Craig, Weiss, Lal, Somayajulu, and S. S. Krishnaswami, the latter from the Physical Research Laboratory in Ahmedabad, developed quantitative and efficient techniques for filtration of oceanic particulate matter of $\geq 1\mu$ size from seawater at different depths up to 5,000 m. These techniques allowed, for the first time, filtration of 10^3-10^4 liters of seawater. Analyses are in progress of mineralogy, inorganic biogenic carbon, and a suite of radioisotopes present in particulates from surface Atlantic and Pacific waters, and several vertical profiles from the deep Pacific, sampled during the GEOSECS expedition.

A large number of dissolved silicon profiles corresponding to dissolved silicon from 10-100-metric tons of water from depths of 0-4,000 m, were successfully collected from several stations in the Pacific Ocean during the GEOSECS expedition. These samples are now being studied by Drs. Craig, Lal, Weiss, and Somayajulu for Si^{32}/Si^{28} ratios for quantitative investigations of oceanic mixing processes.

Dr. Joseph R. Curray, working with Dr. David G. Moore, Naval Undersea Center, San Diego, and with Drs. Russell W. Raitt and LeRoy M. Dorman, has completed a fourth expedition to the northeastern Indian Ocean on Leg V of the Eurydice Expedition. The scientists spent approximately half of their six weeks of ship-time doing geological and geophysical work in the Andaman Sea, and the other half working southwest of Sumatra and south of Java along the Sunda Trench and Island Arc

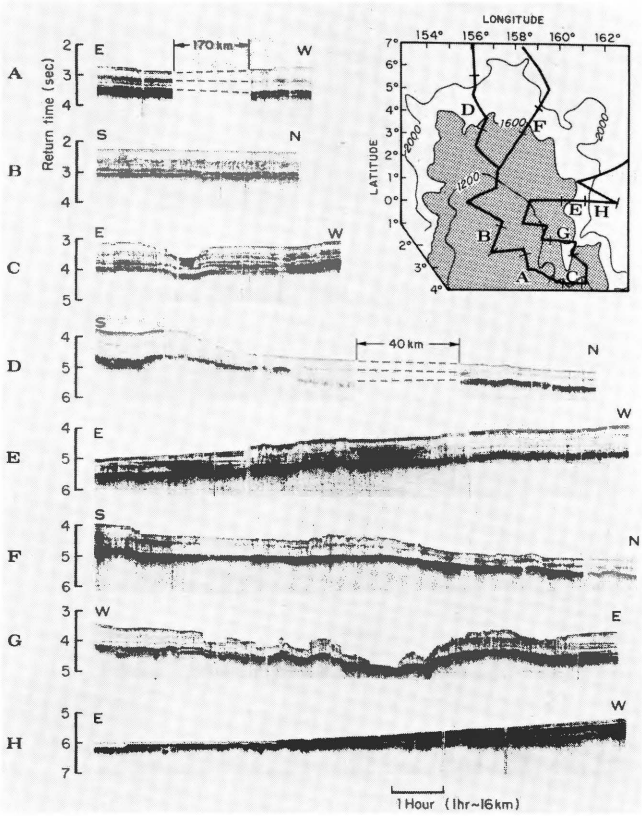


Illustration of acoustic profiles from Ontong-Java Plateau, east of New Guinea, showing differences in style of deformation of strata as function of depth. Suggested interpretations follow: A and B – Shallow plateau. Note sheet erosion (A) and internal disturbance (Neptunian dikes?). C – Cross-section through a sediment slide originating from graben tectonics. Note steep bounding cliffs. D – Rotational slumps apparently generated by withdrawal of support at lysocline. E and F – Smoothing of record by mass flow, and pile-up (?). G – Sediment slides on chert basement, caused by steep slopes and withdrawal of support by dissolution, downhill. Note steepness of remnant stacks that shows high stability of sediment. H – Smoothing of topography by soliflucting.

Dr. Wolfgang H. Berger

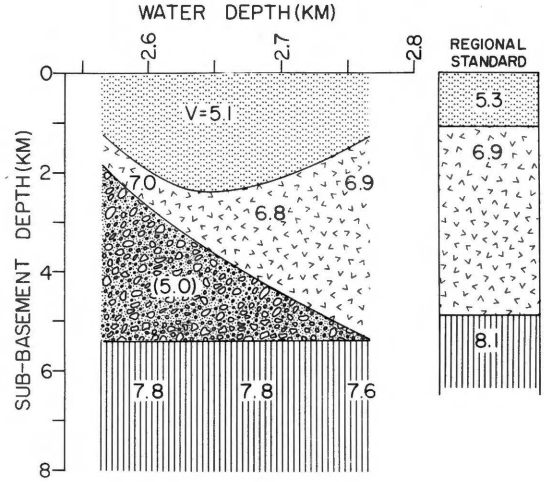


Fig. Schematic of low velocity, low density body beneath the axis of the East Pacific Rise. The numbers represent sound velocities in km/s at the tops of each region. The sound velocity generally increases with depth within each unit. Parentheses indicate that the velocity is not accurately known.

Schematic shows low-velocity, low-density body beneath axis of East Pacific Rise. Numbers represent sound velocities in km/s at tops of each region. Sound velocity generally increases with depth within each unit. Parentheses indicate that velocity is not accurately known.

Dr. LeRoy L. Dorman

system. A portion of the latter half of the cruise will constitute the dissertation research material for two graduate students working with Dr. Curray.

The geophysical work, principally seismic reflection, supplemented by seismic refraction, gravity, and magnetics, has demonstrated that the Andaman Sea is an extensional basin, with sea-floor spreading carrying western Burma and the Andaman-Nicobar Ridge northwestward with respect to the Malay Peninsula. On this basis, the small Burma plate has been defined, and it is apparently responding to the interaction between the larger Indian and China plates.

Several north-south trending zones in the Andaman Sea and extending northward into Burma have been delineated and their geological age predicted. The history postulated suggests that the Andaman Sea did not exist when the Indian plate started plunging beneath the China plate in Cretaceous time (about 130 million years ago). Extension is believed to have commenced in a relative east-west direction in Oligocene time (about 35 million years ago) with the formation of successive north-south geological provinces. The east-west extension changed to a relative northwest-southeast spreading in Pliocene time, about three-and-a-half million years ago, and continues to the present day. Seismicity and heat flow are compatible with this model, which has important implications on the geology, faulting, seismicity, and geological history of both Burma and northern Sumatra.

Dr. Dorman's expedition to the Siqueiros Fracture Zone last year, 1,000 km southwest of Acapulco, Mexico, has provided significant new data on the creation of the ocean floor and has resulted in the designation of that area as a site for drilling a 1-to-2-km-deep hole in the ocean floor under the International Phase of Ocean Drilling. Using ocean-bottom seismographs, Dr. Dorman conducted seismic refraction work, with graduate student John A. Orcutt and visitor Dr. Brian L. N. Kennett, in a manner that allows geologically reasonable variations of seismic velocity with depth instead of forcing the models to consist of a few, thick, homogenous layers. Dr. Dorman demonstrated the existence of a zone of low-velocity material at the base of the oceanic crust beneath the "horst," or elevated block, that marks the axis of the spreading center. Data from the dense coverage of a sonobuoy refraction survey, in cooperation with graduate students Bruce R. Rosendahl and L. Dale Bibee and Dr. Raitt, show that the thickness of this low-velocity zone is apparently confined to the area beneath the "horst," and that its thickness is proportional to elevation of the "horst" above the surrounding region, as shown in the accompanying figure. The gravity data indicate that this zone is of low density as well as low velocity, and thus provides buoyant support for the "horst."

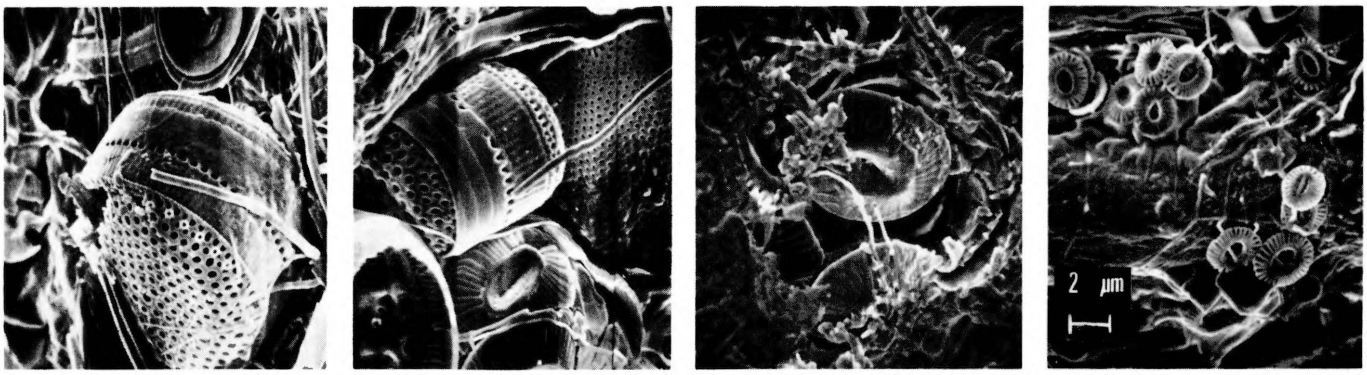
Funding has been received for a seismic-refraction study of the lithosphere east of the Hawaiian Islands. This project, led by Dr. Dorman, a cooperative effort with the University of Washington and the University of Hawaii is centered around a seismic-refraction profile 2,000 km in length that will probe the earth to depths of several hundred kilometers. This work will use ocean-bottom seismographs designed by Dr. William A. Prothero, and will also use chemical explosions (up to seven tons each) for sound source.

The research programs of Dr. Edward D. Goldberg and his associates, Drs. Chi-wu Su and Kathe K. Bertine and John J. Griffin and Minoru Koide, have involved the impact of man's activities upon the ocean system.

The strategies to reconstruct the pollution history of an estuarine environment from sedimentary records have been formulated and tested upon Narragansett Bay deposits collected by Dr. Goldberg's group in Rhode Island.

The sedimentary strata are assumed to hold records of man-mobilized materials that rapidly precipitate out of ocean waters. Two problems in the development of a valid pollution record are (1) the recovery of undistorted, sedimentary-column materials; and (2) the accurate determination of the time of deposition for each stratum sampled. The first hurdle was overcome by the use of open-vented box corers. The second problem was solved by the combined use of a variety of dating techniques: Pb-210 geochronologies, plutonium-238 geochronologies, and the occurrence of bivalve and gastropod shells introduced during major hurricanes.

Readily discernible were increased fluxes of heavy metals (lead, cadmium, zinc, copper, and chronium) into recent strata compared to those of several decades ago. The Scripps scientists have observed similar increases off the western coast of the United States, and other investigators have also



Scanning electron microscope photographs of biological particles, mostly coccoliths and centric diatoms, trapped in J-underway filters during GEOSECS Atlantic Expedition.
Drs. Harmon Craig, S. S. Krishnaswami, Devendra Lal, and B. L. K. Somayajulu

observed like increases off the German coast in the Baltic Sea. One of the curious artifacts of these deposits is elemental carbon in the form of coal, coke, and charcoal, introduced by man as a consequence of his quest for energy. The amounts of such materials approached two percent by dry weight.

The concentrations of many mobilized halocarbons, such as the chlorofluorcarbons used as aerosol propellants and the chlorocarbons used as solvents and cleaners, have been measured in atmospheric and oceanic samples. The oceans do not appear as a primary sink for such materials, for most probably are destroyed in the stratosphere after transfer from the troposphere.

In collaboration with investigators at the University of Wisconsin, Dr. Goldberg's group has compared the lead-210 geochronology for marine and lacustrine sediments with pollen-dating techniques. The diagnostic pollen is ragweed that becomes abundant following deforestation activities. The two techniques were in agreement for recent sediments from Lake Superior.

The principal research activities of Dr. James W. Hawkins and the students working with him have been directed toward an understanding of the origin and evolution of the oceanic crust and the generation of igneous rocks at plate boundaries. A month's survey on R/V *Thomas Washington* was made during the Eurydice Expedition to study the petrology and geophysical properties of the sea floor between the Tonga and New Hebrides trenches and on the Fiji Plateau. Land geological studies were done in Western Samoa and American Samoa, in the Wallis Islands, and on New Caledonia to continue a long-term study of the Samoa-Tonga-Fiji region. One of the results of the expedition was the discovery of a spreading center on the Fiji Plateau characterized by symmetric magnetic anomalies, high heat flow, and fresh, ocean-ridge-type basalt.

Other work included petrologic studies of Miocene volcanic rocks on the southern California borderland and basalts from the East Pacific Rise, the Gulf of California, and from Isla Tortuga, a small volcanic island in the Gulf. Graduate student James H. Natland completed his doctoral dissertation on the petrology of the Samoan Island chain, and co-authored a paper with Dr. Hawkins on the tectonic and petrologic processes of the region. David Clague completed his dissertation on the petrology and history of the Hawaiian-Emperor seamount chain, Richard K. Nishimori is completing his petrologic study of layered gabbro plutons of the Peninsular Range batholith and Rodey Batiza has started a project to study the origin and evolution of seamounts. Lawrence A. Lawver, Stephen Hartzell, and Batiza are participating in a petrologic-geochemical-geophysical study of the Fiji Plateau.

The research projects of Dr. Miriam Kastner and students have concentrated on the effects of host rocks and surface chemistry on the diagenesis of deep-sea sediments. Experimental work on the kinetics of montmorillonite to illite conversion (with Dr. Jeffrey L. Bada) has been completed. The experiments show that in carbonate sediments the above conversion is enhanced. This result has important implications for geochemical, mass-balance calculations, for interstitial water analyses interpretations, and for oil prospecting.

An experimental study (with graduate student John B. Keene) on the transformation of siliceous oozes to porcelanites and cherts is under way. The main objective is an experimental determination of the inorganic controls on the maturation process opal-A → opal-CT → quartz. The three main preliminary results are these: (1) the kinetics of the maturation sequence is strongly affected by the composition and texture of the host sediment, as shown in Table 1. Already at the end of one month, the experiments with carbonate showed highly corroded siliceous tests, but as a result of opal-CT crystallization, preferentially on the surfaces of foraminifera tests, and cementation by silica (see accompanying three-part illustration), silica concentrations in solution were lower than in the experiments without carbonate, in which siliceous tests partially dissolved but no crystallization of opal-CT was observed; (2) the diagenetic potential of diatoms is much higher than that of radiolarians; and (3) the reordering and recrystallization of opal-CT is affected by certain impurities, such as Mg and Al.

The rather new technique ESCA (Electron Spectroscopy for Chemical Analysis) for surface chemistry of deep-sea sediments was tested on siliceous oozes. Preliminary results show that several elements previously thought to be concentrated on the surfaces of siliceous oozes (for example, Ba) do not show the expected concentrations. These determinations might affect future interpretations of chemical gradients in the ocean as a function of depth.

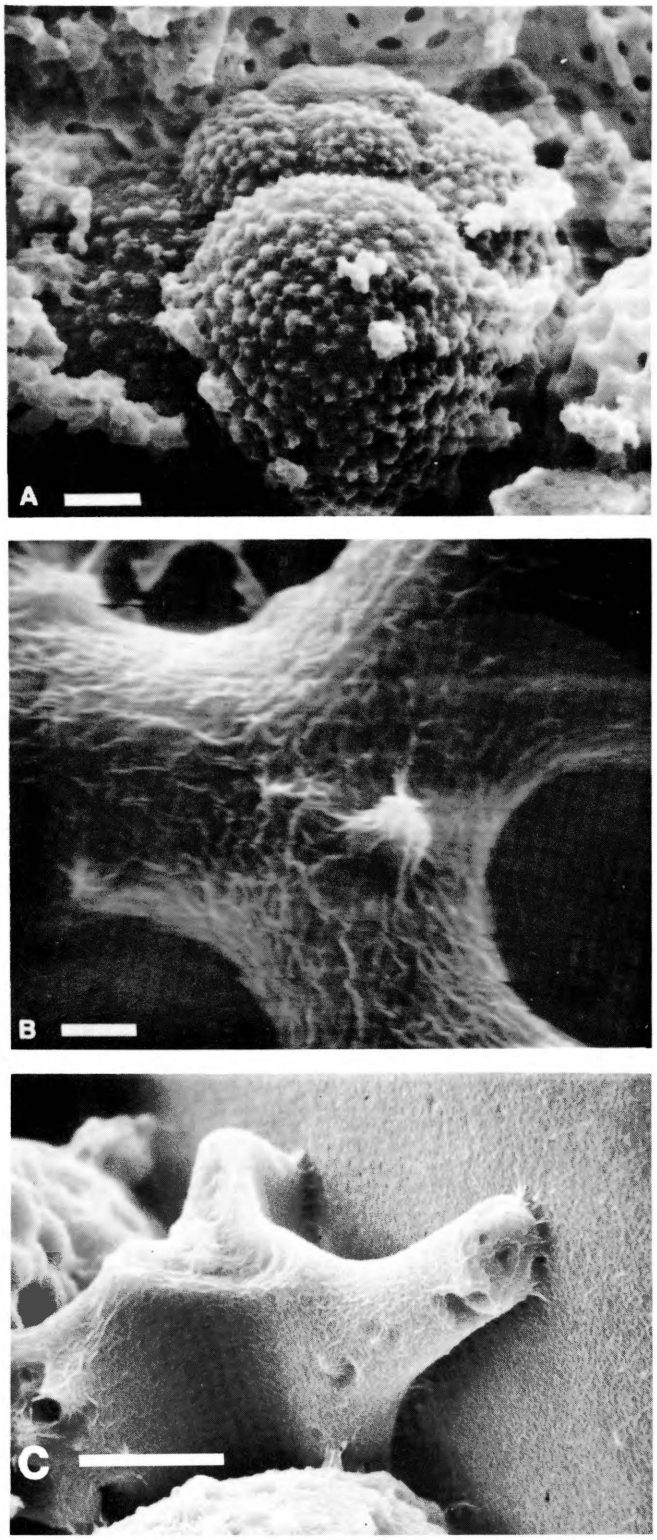
A report on diagenesis of basal sediments of Leg 35 of the Deep Sea Drilling Project (DSDP) is in press (DSDP Vol. 35). The main results are three: (1) chemical gradients in interstitial waters indicate the depth intervals for sinks and sources of major and minor elements; (2) the Fe/Al ratio of authigenic smectite associated with phillipsite is higher than of smectite associated with clinoptilolite. The chemistry of both smectites reflects the chemical composition of their precursor(s); and (3) the formation and chemical composition of diagenetic aluminosilicates within porcelanite beds depend on the presence and abundance of volcanogenic material.

Keene completed a manuscript on cherts and porcelanites taken from the North Pacific by Leg 32 of DSDP. The principal conclusion was that the kinetics of silicification varies with the nature of the host sediment. Most chert nodules form earlier in calcareous oozes, and bedded cherts in clay form later. He also published (with Dr. Kathe Bertine) a manuscript on submarine barite-opal rocks of hydrothermal origin.

Sharon S. Stonecipher, a graduate student, completed a manuscript on the distribution of phillipsite and clinoptilolite in deep-sea sediments. Microprobe analyses of clinoptilolites show that clinoptilolites from carbonate sediments have less Si and K and more Ca than clinoptilolites from clayey sediments.

Table 1. Diagenesis of siliceous oozes: silica values of hydrothermal experiments, 150°C, 1 month.

Experiment No.	Starting Materials	$Si(OH)_4$ μmoles/l
Ia	0.1 g Radiolarians + 15ml seawater	2430
IIa	0.1 g Radiolarians + 0.1 g Foraminifera + 15 ml seawater	1885
IIIa	0.1 g Radiolarians + 0.1 g montmorillonite + 15 ml seawater	2280
IVa	0.1 g Radiolarians + 0.05 g Foraminifera + 0.05 g montmorillonite + 15ml seawater	1970
Xb	0.1 g Radiolarians + 0.5 M NaCl and 0.06 M $MgCl_2$ solution	6500
Xa	0.1 g Radiolarians + 0.1 g Foraminifera + 0.5 M NaCl and 0.06 M $MgCl_2$ solution	2420



Scanning electron microscope photographs of opal-CT embryos and cementation, observed in hydrothermal experiments with carbonate. Photo A shows opal-CT embryos crystallized preferentially on surface of foraminifera. White bar in lower left represents 20 microns. Photo B shows an isolated opal-CT embryo crystallized on surface of radiolarian test. White bar in lower left represents two microns. Photo C is of a radiolarian test cemented to surface of a foraminifera test. White bar in lower left represents 20 microns.

Dr. Miriam Kastner

Dr. J. Douglas Macdougall arrived at Scripps in July 1974, and began setting up laboratory facilities for geochemical and geochronological studies of oceanic rocks and sediments. Work with graduate student Mark E. Andersen and laboratory assistant J. L. Goldberg has produced a number of interesting results and promising avenues for further research.

Studies of uranium concentrations and microdistributions in oceanic rocks have revealed large-scale concentrations of this element in alteration-produced phases, particularly in clay minerals. Several other elements, notably potassium, are also concentrated in these phases, and the K/U ratios indicate that altered oceanic rocks may be an important "sink" in the geochemical budgets of these elements. The discovery of the uranium concentrations is also important in considerations of the helium flux into seawater, and of oceanic heat flow.

Attempts to apply fission-track dating to oceanic basalts have met with little success. Extensive investigations of the effects of thermal annealing of fission fragment tracks in oceanic rocks indicate that the radiation damage relaxes in basalt glass, even at sea-bottom temperatures, over long time periods, thus invalidating direct application of this dating method. Attempts are under way to apply various correction procedures and to extract rare uranium-rich and more retentive phases from oceanic rocks.

Preliminary leaching experiments indicate that up to 25 percent of the total concentrations in basaltic rocks of a number of transition metals, including Fe, Mn, Co, and Cu, are in easily leachable sites, presumably along grain boundaries. All of these elements are in "excess" in pelagic sediments pointing to submarine weathering of basaltic rocks as a plausible source. These experiments are part of a more general study of basalt alteration processes.

Work with alpha-particle-recording plastics has resulted in what may be a new method for measuring growth mechanisms of manganese nodules. Autoradiography using these plastics results in a precise map of the alpha activity on, for example, a section through the center of a manganese nodule. In the outer portions of nodules, most alpha activity is caused by Th^{230}, and its decay with depth can be followed nondestructively with a resolution of a few tens of microns using this method. Such resolution is currently unobtainable by conventional alpha-spectrometry techniques. In unrelated studies using these same alpha particle detectors, graduate students Andersen and John A. Welhan are investigating the feasibility of measuring radon emissions from hot springs and other natural waters by detecting alpha particle tracks in the plastic detectors. If it is successful, this technique could prove to be a particularly simple, fast, and economical method for measuring radon emission as a tool in earthquake prediction.

In addition to the directly ocean-related activities described above, Dr. Macdougall is continuing research on the early history of carbonaceous meteorites begun at UC Berkeley early in 1974. This work involves studies of radiation effects, searches for indicators of the original presence of now-extinct transuranic elements, and chemical characterization of individual mineral phases. This collaborative research effort also involves personnel from the chemistry departments at UCSD, UCLA, and UCB.

Dr. Robert L. Fisher, in collaboration with Dr. Celeste G. Engel, completed the petrographic description and field relation interpretation of 57 dredge hauls of granitic to ultramafic plutonic and volcanic rocks collected from the bifurcating, seismically active, submarine ridge system in the western Indian Ocean. A definitive paper by Drs. Engel and Fisher is imminent in the *Bulletin of the Geological Society of America;* more specialized studies of these igneous rocks, with Dr. C. G. Engel and other collaborators, continues.

Field work directed by Dr. Fisher on Eurydice Expedition was an intensive dredging-bottom, photography-seismic, reflection-magnetic study, under National Science Foundation sponsorship, of the vicinity of Challenger Deep, southwest of Guam in the Marianas Trench. Challenger Deep, the deepest part of the world oceans, was established by several methods on this *Thomas Washington* exploration as 10,915 ± 20 meters deep.

The field program's aim was to collect well-located igneous rocks or consolidated sediments actually present on the steep, rugged, lower flanks of the active "subducting" trench. Such ground truth collections provide needed restraints to structural models. Two hauls on the offshore flank, at 9,500- to 8,100-m depth, were weathered tholeiitic basalts. Five hauls on the nearshore flank, at 10,450-m to 6,100-m depth overall, were granitic to intermediate plutonics, fresh to somewhat altered ultramafic plutonics, mafic volcanics and volcanic breccias, metavolcanics, lithified sediments, and agglomerates. Except for the silicic plutonics, the Challenger Deep samples are like plutonic rocks collected by Dr. Fisher from similar, deep settings in the Tonga Trench, second in depth only to Challenger Deep.

Editorial board work and data interpretation by Dr. Fisher on the

UNESCO-sponsored and internationally prepared *Atlas of Geology and Geophysics of the International Indian Ocean Expedition 1959-65* was completed; the Moscow-printed atlas appeared in late September 1975. Dr. Fisher and co-workers continued data compilation and structural interpretation of Sheet 5.09, the southern Indian Ocean to 50°S, for the *General Bathymetric Chart of the Oceans (GEBCO),* Fifth Edition, for which he is scientific coordinator.

William R. Riedel and Annika B. Sanfilippo have collaborated with Italian and Dutch researchers in micropaleontological investigations of late Tertiary sediments on Sicily and Crete, with the aim of providing more precise correlations and paleoecological interpretations. They have also begun to correlate Cretaceous radiolarian assemblages of Europe with the zonation established on the basis of Deep Sea Drilling Project cores.

Patricia S. Doyle and co-workers have continued to apply microscopic fish skeletal debris (ichthyoliths) for the dating of pelagic sediments lacking other microfossils. In addition to being solution-resistant, ichthyoliths are proving to be less susceptible to reworking on the deep-sea floor than are some other, more easily transported microfossils, and are settling some questions of age not resolved by longer-studied groups such as foraminifera and radiolarians.

Study of currents in submarine canyons, by Dr. Francis P. Shepard, was considerably benefited by an expedition to the Rio Balsas Delta area off the west coast of Mexico, where a complete record of pulsating turbidity currents was obtained during a period of high swell that showed a relationship to two, high, spring tides. Also, it was learned that the close tidal relation of upcanyon and downcanyon alternations, reported previously for records in excess of 250 m, occurs at considerably greater depths in three areas where the tidal range is much smaller than in the areas from which records had been obtained previously. In these new areas with small tidal range, the upcanyon and downcanyon alternations also have a higher frequency. Additional information showing comparison between current records from adjacent stations along the axes of submarine canyons appears to indicate that internal waves may often advance down submarine canyons, particularly in areas of small tidal range. Previously, it was thought that they were almost always advancing up the canyons.

During the Rio Balsas Expedition, fathometer records indicated the presence of a 45-km belt of large, symmetrical, sediment waves along the Mexican coast near Manzanillo, which appear to be confined within depths of 320 and 770 m.

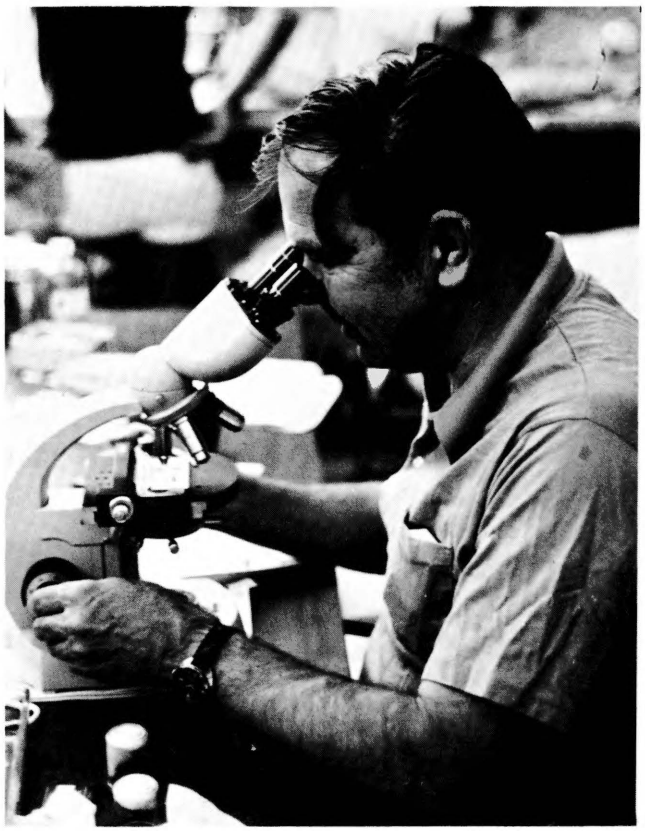
The results of this past year's studies by Dr. Shepard have been published in *Deep-Sea Research* and *Marine Geology*.

Marine Biology Research Division

Investigations in the Marine Biology Research Division embrace experimental, descriptive, biological disciplines, including physiology, biochemistry, microbiology, developmental and systematic biology, and ecology of the sea. Many of the studies are comparative in nature, and structures, events, or processes are examined in a wide range of marine and terrestrial organisms. An objective is to gain new insight into fundamental problems of biology and medicine by a better understanding of marine organisms and the manner in which they adapt to life in the sea.

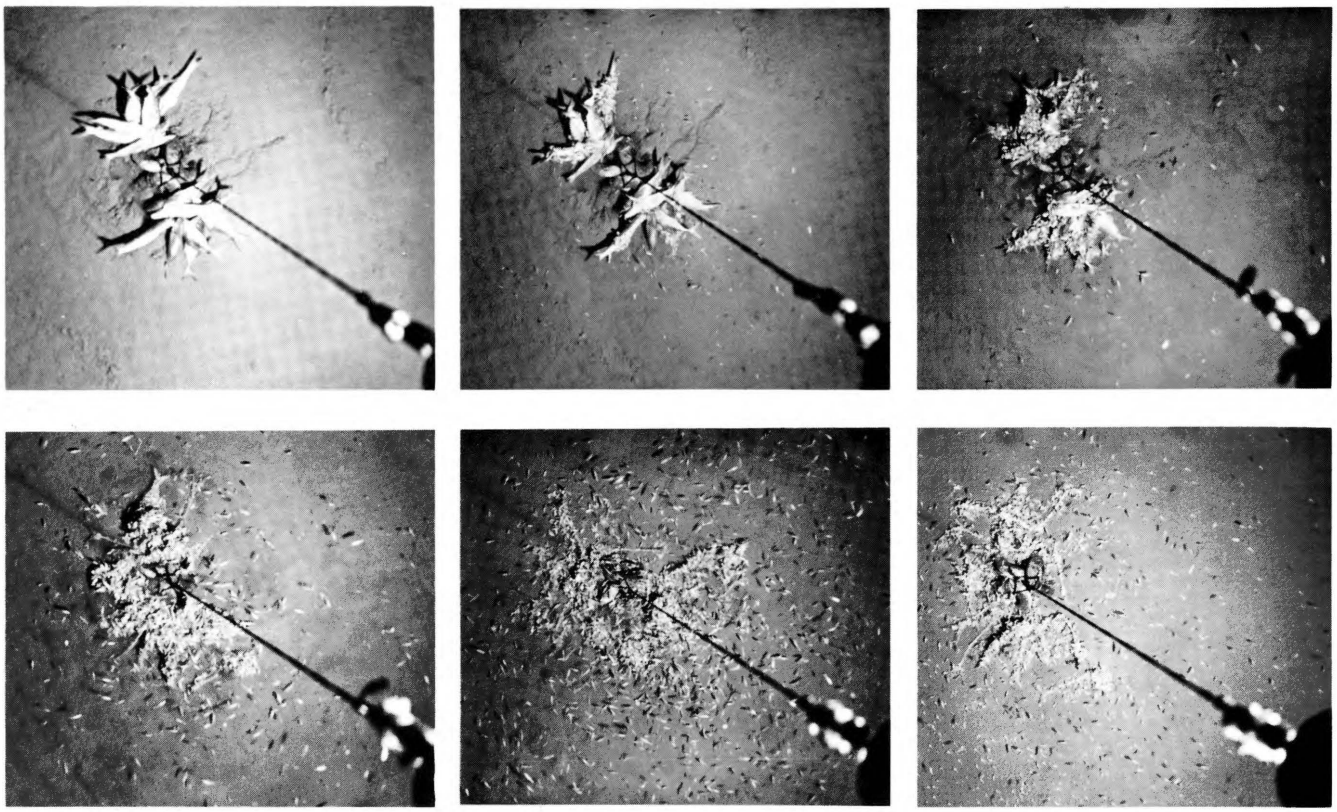
Dr. Nicholas D. Holland has continued to investigate the reproductive biology and embryology of feather stars. This work has been carried out at the Misaki Marine Biological Laboratory in Japan, and at the laboratory of the Marine Biological Association of the United Kingdom, Plymouth, England. From monthly samples of the Japanese feather star, oogenesis and spermatogenesis have been described in detail. These descriptions are prerequisites for planned work on the environmental controls and the endocrinology of reproduction in this species.

Of particular interest is the discovery that the Japanese feather star is a veritable sea calendar, since all the animals spawn at about 3 p.m. on the day of a first-quarter moon or last-quarter moon during the first half of October. The concentration of all this animal's spawning activity into one hour per year raises obvious questions about the environmental controls of the remarkable synchrony; moreover, the predictability of the spawning date makes possible many studies of the terminal events of gametogenesis. For example, ovaries were fixed for transmission and scanning electron microscopy every 15 minutes throughout the morning and the afternoon of the day of spawning. The result was a kind of time-lapse movie of the nuclear and cytoplasmic changes that take place as primary oocytes mature into ripe eggs. By the same approach, Dr. Holland and Professor Katsuma Dan, Tokyo Metropolitan University, have demonstrated a clear-cut instance of ovulation. The ovulating oocytes pass from the ovarian tissue into the ovarian lumen during an hour-long passage through the germinal



Project SCORE (Scientific Cooperative Operational Research Expedition) concluded a three-year Bahama Banks research program supported by the National Oceanic and Atmospheric Administration's Manned Undersea Science and Technology (MUSA&T) office. Participants during 1974-75 investigations included, from Scripps, Dr. Francis T. Haxo, shown examining dinoflagellates isolated from coral hosts, and graduate student Arthur T. Ley, who is examining a sea lily (Crinoid) in a plastic bag. Their work was conducted in the shore laboratory of SCORE's home port, Freeport. Director of MUSA&T was a Scripps graduate, Dr. Morgan Wells.

National Oceanic and Atmospheric Administration



Time-lapse photographs show amphipods consuming dead fish used as bait in a free-vehicle camera-lowering in Philippine Trench at 9,600-m depth. After about 16 hours, little more than bones of fish remain.

Dr. Robert R. Hessler

epithelium (see illustration).

Thomas Ermak, working under Dr. Holland's chairmanship, finished his dissertation on the cell kinetics of the tissues of tunicates. A highlight of the work was the discovery that the mucosa was a renewing cell population in many parts of the tunicate digestive tract; by contrast, the digestive mucosa of other invertebrates studied have been expanding or static cell populations. It is especially interesting that tunicates have renewing gut cell populations of the kind known in the vertebrates, since tunicates, as invertebrate chordates, have close affinities to the vertebrates.

Research in Dr. David Epel's laboratory centers on the changes that occur in the egg when embryonic development is initiated at fertilization. The major finding that release of calcium from intracellular stores was a primary event of fertilization, has led — in research conducted by Dr. James Johnson, a post-doctoral researcher — to the important discovery that activation also results in the loss of a number of cell-surface proteins and glycoproteins. These proteins seem to function as suppressors of egg metabolism and their removal at fertilization results in egg activation.

Continuing work on the block to polyspermy, Dr. William Byrd, a post-doctoral fellow, and Franklin Collins, a graduate student, in the Department of Biology at UCSD, have found that there is no rapid alteration of the egg that results in the block to polyspermy. This concept, considerably different than past thinking on this subject, has necessitated a re-evaluation of the entire problem. Collins has also been carrying out an important study on the changes that the sperm must undergo before it can fertilize the egg, known as the acrosome reaction. This occurs when the sperm contacts "egg jelly," a collection of acidic glycoproteins surrounding the egg. Collins has learned this acrosome reaction probably results from an influx of calcium from the seawater and that the acrosome reaction exposes substances on the sperm which allow them to attach to eggs.

Dr. Kenneth H. Nealson and his associates have been concerned with the biochemistry and ecology of luminous bacteria, ubiquitous inhabitants of the seas which are most familiar as symbionts in many luminous fishes (*Photoblepharon, Leiognathus, Monocentris*).

Laboratory studies have revealed that light emission is controlled by a complex mechanism that shuts off luminescence when the bacteria are not in symbiotic association. The studies led to the hypothesis that such bacteria are facultative symbionts, capable of existence either as luminous symbionts, or as free-living, non-luminous heterotrophs. Field measurements of *in situ* bioluminescence have confirmed this hypothesis. Experiments carried out on the R/V *Alpha Helix* in conjunction with Charles R. Booth have revealed that the free-living luminous bacteria are not active in light emission, and that it is possible to measure the light output of a single bacterial cell when it is actively luminous.

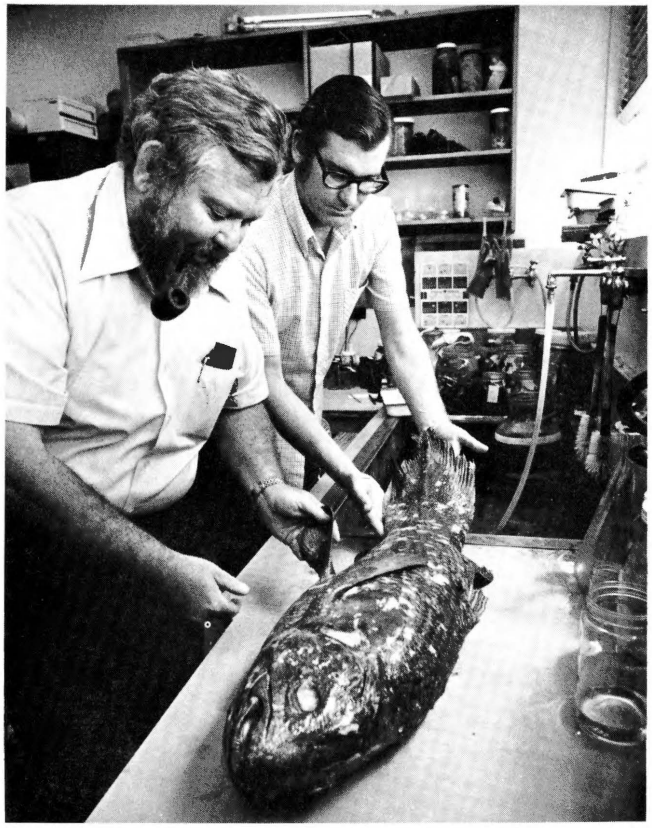
Studies by Edward G. Ruby, a graduate student, of many, different, symbiotically associated, luminous bacteria indicate that as a group, they are unique in their excretion of large amounts of organic acids — specifically pyruvate and oxalacetate — while growing aerobically and emitting light. He is now studying in detail the species of bacteria which he isolated and identified from the luminous fish *Monocentris japonicus*.

Collaborative studies by Dr. Nealson with Dr. J. Woodland Hastings at Harvard have revealed a dependence of bioluminescence upon oxygen tension in a rather unique way. As oxygen tension is lowered, light emission, an oxygen-requiring process, increases. While this is true for all symbiotic forms examined, the pattern is not seen with one species of luminous bacteria that is thought to be a true "free-living type."

Dr. Nealson's taxonomic studies, with Australian collaborator Dr. John Reichelt, and Dr. Hastings, have shown that the symbiosis is a species specific association, with various individuals of each species of fish having only one species of bacteria. Each fish possesses a pure culture of luminous bacteria in its light organ. The problem of how the fish obtains and maintains the proper species of bacteria is an exciting area of future study.

Dr. Anita Hessler, in collaboration with Dr. Irving Crawford of Scripps Clinic and Research Foundation, La Jolla, has been studying the genetics of luminous bacteria, with a view to elucidating the genetic organization of the tryptophan synthesis pathway.

Dr. Claude E. ZoBell has continued to study the mechanisms whereby deep-sea pressures influence the physiological activity rates of bacteria with particular reference to sulfate reduction. He participated in a workshop on baromicrobiology at Rensselaer Polytechnic Institute, Troy, New York, where he presented the keynote address on the development of apparatus and methods for demonstrating the biological effects of deep-sea pressures.



Dr. Richard H. Rosenblatt, professor of marine biology and curator of marine vertebrates, at left, and Joseph F. Copp, museum scientist, prepare to dissect rare coelacanth fish, a so-called "living fossil" acquired by the institution for study and exhibit.

Photo courtesy of San Diego Union

New species frequently turn up and are described in the laboratory of Dr. Ralph A. Lewin. Several have been of specific interest. For example a new alga, *Chlamydomonas melanospora,* has the ability to produce what may be called "micronodules" — actually zygospores encrusted with oxides of manganese. The mineral nature of these micronodules was demonstrated by Dr. Meinhard Schulz-Baldes (a post-doctoral fellow from Institut für Meeresforschung, Bremerhaven) by the use of atomic absorption spectroscopy. Another newly described organism, a purple bacterium *Chromobacterium* sp., which was isolated from the central North Pacific, produces a potent antibiotic. This received intensive chemical study, and formed part of the doctoral thesis of Ray Anderson. *Synechocystis didemni,* so far the only prokaryotic alga known to possess chlorophyll *b* as well as chlorophyll *a*, has been described from mangrove swamps in Baja California, where it was collected on cruises of the R/V *Dolphin.*

With Dr. Joan G. Stewart, Dr. Schultz-Baldes has studied the pathway of lead in a marine food chain. They showed that Pb adsorbed to the thalli of *Egregia,* a brown alga, was taken up by abalone *(Haliotis)* feeding on this seaweed roughly in proportion to the Pb concentrations in the original seawater. It was accumulated in the liver, kidney, and gonad, but seems to be fairly efficiently excluded from the muscles of the foot, which is the edible part of the abalone.

Since the diatom, which is absolutely dependent on silicon, offers an experimental system *par excellence* for exploring the biological role of silicon, Dr. Benjamin E. Volcani and his associates are using this organism as a "living laboratory" for reconnoitering the biochemical role of silicon and then testing their positive findings in mammalian tissues and cells.

Dr. Charles W. Mehard is studying silicon transport in diatoms, rats and fish. Electron-probe, X-ray microanalysis studies of freeze-substitution in rat-liver preparations have shown that Si is present *in situ* in the cell organelles. Dr. Mehard has overcome one of the obstacles to Si research — the short half-life of ^{31}Si — by demonstrating that Ge, a chemical analog of Si, mimics Si transport and accumulation. Thus, in a new approach to understanding the Si requirement for bone formation, he has followed the course of ^{68}Ge incorporation in developing bones of young rats by injecting the mothers with ^{68}Ge during gestation and lactation. In other experiments, Dr. Mehard fed anchovies with diatoms that had been labeled with ^{31}Si or ^{68}Ge. Both elements were taken up by the liver and dorsal muscle of this fish, whether ingested from the soluble pool or after having been incorporated in the diatom shell. This latter finding adds another dimension to study of the silicon cycle of the oceans.

The pathogenic effects of silica dusts are well established. Since silicon, as the predominant element in these dusts, is implicated as a causative agent, Dr. Patricia A. Burnham is investigating the effect of monosilicic acid and polymeric silicic acid on the growth of rat-lung fibroblasts and cat-lung epethelial cell cultures. At concentrations of $3x10^{-4}$ Molar to $3x10^{-3}$ Molar, monosilicic acid did not affect cell growth, but polysilicic acid, at 10^{-3} Molar, produced marked inhibition of growth and vacuolization.

Graduate student John S. Paul has shown that, in both diatoms and the green alga *Chlamydomonas reinhardi,* the oxidation system for the photorespiratory metabolite, glycolic acid, is located in the mitochondria and that this oxidation is linked to the mitochondrial electron transport system. He has been able to characterize a new enzyme for glycolic acid oxidations: *i.e.,* glycolate: cytochrome *c* reductase. Thomas W. Okita, another graduate student, in investigations of the nature of the silicon requirement in *Cylindrotheca fusiformis,* has found that four protein fractions are synthesized only in the presence of silicon. The major protein fraction contains thymidylate kinase activity.

Dr. Francis T. Haxo and his associates extended their researches on the growth of toxic dinoflagellates, chloroplast pigmentation of algae *vis-à-vis* phyletic affinity, and light-induced changes in the photosynthesis apparatus of marine algae.

Preliminary studies of the light-temperature dependence, for growth of a La Jolla isolate of *Gonyaulax catenella,* revealed temperature tolerances similar to those reported for the same species isolated from the colder waters off northwestern Washington. However, maximum cell densities of the southern form were reached at significantly higher irradiance levels. The effect of these parameters on photosynthesis and on saxitoxin production is under study.

During the year, Barbara B. Prezelin finished her doctoral dissertation on the characterization of the peridinin-chlorophyll *a* proteins in the dinoflagellates *Glenodinium* sp. and *Gonyaulax polyedra* and their role in photosynthetic light adaptation. An important discovery was that these peridinin proteins account for most of the seven-fold increase in peridinin observed at low-level growth irradiances. Further evidence suggested that the plasticity of these components is an adaptive mechanism for more effective photon capture for photosynthesis under limiting light conditions in the oceans.

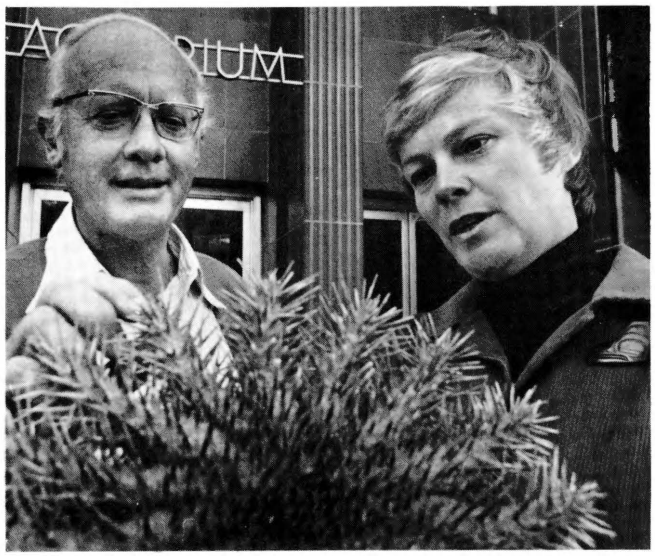
Photoadaptation with depth in marine green algae, which lack the classical accessory pigments, has been largely unexplored. Preliminary observations by graduate student Arthur C. Ley and Dr. Haxo — both of whom participated in April in a Hydrolab Mission off Grand Bahama Island (see illustrations) that was sponsored by the National Oceanic and Atmospheric Administration, and the Perry Foundation, Inc., and the Harbor Foundation, Inc., of Florida under the name of SCORE (Scientific Cooperative Operational Research Expedition) — suggest that the adaptive mechanisms may be complex and diverse. For example, *Caulerpa mexicana* appears to adapt to the changing light field with depth in two ways; first, to increase the total number of photosynthetic units, and second, to increase the size of the light-harvesting component of each photosynthetic unit.

Dr. Elizabeth Kampa Boden, continuing studies of photoenvironment and the behavior of mesopelagic animals in the sea, has placed emphasis this year on the effects of these living communities and of their detrital remains on the transmission of daylight in the upper 1,000 m of the ocean off southern California. Data on the contribution of such biological material to the reduction of light reaching mesopelagic depths at a number of stations in the waters off San Diego have been gathered and are now being assessed.

The remarkable productivity of corals and the nutrition of the myriads of small fishes in coral-reef areas attracted the interest of Dr. Andrew A. Benson. On the Great Barrier Reef in 1973, he observed that many small fish were "nipping" at the coral surface without doing significant damage. Analysis of the mucus exuded by all corals revealed considerable amounts of wax ester, a major, energy-storage, sub-reservoir in coral. Such wax is relatively unavailable to all but fishes capable of gnawing or crushing the hard coral skeletons. A yet unknown but possibly important fraction of the food of small fishes and other "mucus-feeders" stems from its wax and triglyceride content. Study of the role of mucus as a carrier for energy- and

A scanning electron micrograph of lumenal surface of the germinal epithelium of Japanese feather star, about noon on day of spawning. Two ovulating oocytes are squeezing through circular openings in germinal epithelium. Such ovulation probably takes place in many invertebrates, but chances of seeing it in progress are vanishingly small. Ovulation in Japanese feather star is easy to study, since spawning date can be predicted from lunar calendar.

Dr. Nicholas D. Holland



Dee Benson shows Crown-of-Thorns starfish (Acanthaster planci) *she brought back from Guam to her husband, Dr. Andrew A. Benson, professor of biology, who is studying animals that eat coral, and, more particularly, their digestive processes.*

Photo by John Price, courtesy of San Diego Union

phosphorus-rich lipids was extended in subsequent studies aboard R/V *Alpha Helix*. In the 1974 Nimpkisk Expedition in British Columbia coastal waters, Dr. Benson studied mucous production in Pacific salmon, and demonstrated their rapid exudation of phospholipid engulfed in mucus. The numerous commensal parasites living on fishes appear to have done so partly to use mucus as a source of phosphate and fatty acids.

In an expedition to Isla Clarión, Baja California, Dr. Benson and his group of biologists studied the symbiotic coral system and its biochemical efficiency with John Patton, research assistant, and Dr. Samuel Abraham, Bruce Lyon Memorial Research Laboratory, Oakland. He recognized the importance of acetate assembly by the symbiotic algae of corals to produce energy-rich fatty acids and wax esters stored by the coral.

The doctoral research of Patton has revealed a novel lipid digestive process used by fishes and some other animals to utilize wax esters in their diets. The process differs markedly in its physical procedures from the well-known pancreatic lipase digestive system for fats.

Dr. Denis L. Fox, an invited contributor to the Philadelphia Zoo's Centennial Symposium on Scientific Research in Zoos, spoke on "Selective uptake and display of ingested pigments by flamingos. A review and some continuing puzzles."

Sea anemones of the plumose genus *Metridium* are among the prominent, fine-particle consumers of North American and European coasts, and also of deeper, cooler waters. Although their body-colors are polychromatic, the ovarian tissues and eggs of all ripe females exhibit red coloration because of the storage of astaxanthin as the sole, or greatly preponderant, carotenoid. Dr. Fox and Donald W. Wilkie, director of Scripps's Vaughan Aquarium-Museum, have collaborated in an extended search for the dietary molecule or molecules metabolized by *Metridium* as a precursor to the ovarian astaxanthin. Although experiments are still in progress, to date the carotenoid metabolism of the anemone *Metridium* recalls somewhat that of certain crustaceans, as well as of flamingos, studied earlier.

In the laboratory of Dr. Theodore Enns, the mechanisms of carbon dioxide transport in animals and plants are being analyzed. In collaboration with Dr. Esther Hill of the UCSD School of Medicine, he has studied carbon dioxide diffusion capacities of mammalian lungs. The relative diffusive transport of CO_2 and CO is not necessarily proportional to the inverse ratio of square roots of molecular weights multiplied by relative solubility of the gases in water. Inhibition of lung tissue-associated carbonic anhydrase reduces $^{14}CO_2$ diffusion by a factor of about two, suggesting that carbonic anhydrase facilitates CO_2 transport through the tissue.

In studies of plankton carbonic anhydrase, the enzyme was demonstrated in a variety of plants and animals. It was found that plant and animal carbonic anhydrase activities can be separated by acetazolamide inhibition. Dr. Enns, in collaboration with Dr. Thomas Berman, Kinnert Limnological Laboratory, Tiberias, Israel; Dr. Dale A. Kiefer, and graduate student John E. Burris showed that phytoplankton growth at ocean pH was strongly reduced by carbonic anhydrase inhibition, while growth at lower pH was unchanged. This is compatible with the concept that carbonic anhydrase facilitates CO_2 transport in these plants, and is necessary for optimum growth.

Studies of the effects of environmental factors on protein structure and function were continued in the laboratory of Dr. George N. Somero. Interest lay (1) in the perturbing effects of physical (temperature and pressure) and chemical (salt content and composition) parameters on enzymes, and (2) in the adaptive changes in the enzymes that act to overcome environmental stresses.

The major achievement of the past year came in the discovery of a new mechanism of catalytic rate enhancement. By examining the effects of solutes that alter water structure near the enzyme, it was determined that a major energy change is associated with the exposure to, or withdrawal from, water or protein groups (peptide backbone linkages and amino-acid side chains). For example, the exposure of a charged, amino-acid side chain during catalysis could release sufficient energy to enhance significantly the rate of the reaction. Salts modify these energy changes. Thus, a new mechanism of salt activation and inhibition of catalysis was also discovered. If the exposure of a charged group occurs, therefore, in the presence of certain salts, the energy change accompanying the group's hydration is greatly reduced and, as a consequence, the energy released to "drive" catalysis is also lessened. Salt-activation effects may involve facilitating the dehydration of groups that must be withdrawn into the enzyme during catalysis.

The most outstanding event in the deep-sea program conducted by Dr. Robert R. Hessler this year was a cruise on R/V *Thomas Washington* to study benthic communities in the Philippine Trench. Nearly all the time was spent sampling two sediment ponds at depths in excess of 9,600 m. Success was achieved in obtaining quantitative box cores, trawl samples, trap samples, camera surveys, baited-camera records, bottom-current records, and bathymetric surveys.

One of the surprising results of this cruise was the discovery of considerable amphipod activity at the bottom. While one cannot quantify this, it appears that amphipods may occupy a far more important position in trench communities than is the case elsewhere in the deep sea.

The samples obtained on this cruise will give for the first time a glimpse of community structure in hadal depths at the most critical ecological level, that of the environment of the individual organism.

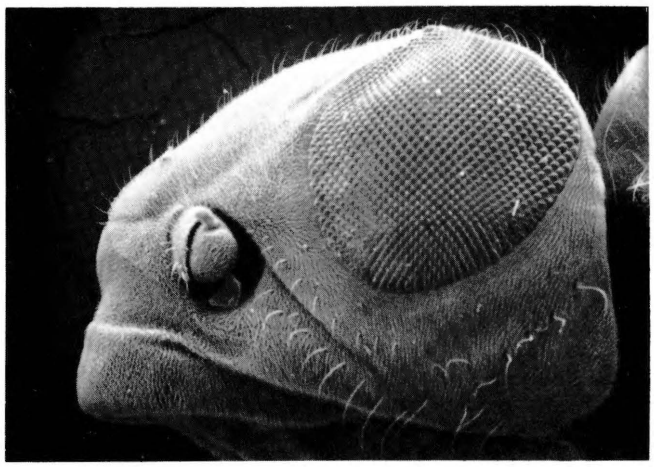
Dr. William A. Newman and associates have been continuing work on benthic crustaceans. A revision of the Balanomorpha (acorn barnacles) of the world, in collaboration with Arnold Ross, San Diego Museum of Natural History, is nearing completion. It includes a catalog of, and guide to, the literature on all living, and most extinct, taxa.

Collections made during several expeditions to Panama by Dr. Newman; by Dr. Alan J. Southward, Plymouth Laboratory, England; and by the Smithsonian Institution, Washington, D.C., under the direction of Dr. Meredith L. Jones, have provided sufficient materials and data to form a

monograph on the barnacles of the region. Results include the first evidence for an amphisthmic distribution of an abundant marine invertebrate attributable to introductions through man's activities. The species, *Balanus pallidus* Darwin, came from West Africa to the Caribbean by ships well before 1850. The species now also ranges in the eastern Pacific, from central Mexico to Ecuador, but whether it got there from the Indo-West Pacific, or by transisthmic migration through the Panama Canal, has yet to be resolved.

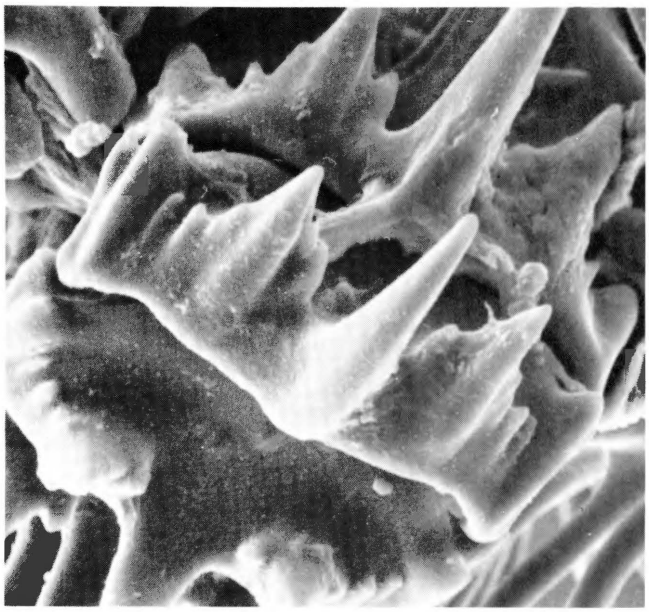
The doctoral researches of Raymond Bauer and Larry E. Ritchie have revealed interesting features of the biology of certain crustaceans. Bauer's morphological and behavioral analyses of grooming in caridean shrimp demonstrate that while grooming is primarily related to a swimming mode of life, it is essential in maintaining chemosecretory, reproduction, and respiratory organs. Ritchie's investigation of coadaptations between a local porcelian crab and a parasitic barnacle (rhizocephalan) has resolved how the larval parasite circumvents the defense mechanisms of the host in establishing the infection, and how it diverts virtually all of the host's resources to its perpetuation and reproductive activities.

Dr. Carl L. Hubbs continued his researches throughout the year, publishing three papers in collaboration with Robert Rush Miller, University of Michigan, that dealt with the systematics and distribution of freshwater fishes of southeastern Mexico. Several papers on marine mammals of the Pacific Coast were completely or largely prepared, with associates, along with a note by him and Joseph R. Jehl, Jr., San Diego Museum of Natural History, giving the first record of fossil birds on Isla de Guadalupe, Baja California. Revisionary studies on several groups of West Coast fishes were brought nearer to completion. The world revision of the hagfishes (Myxinidae) was materially advanced.



Scanning electron micrograph of "fish-faced" fly, Lipochaeta slossonae, *showing small antenna in pit, flattened jaw, and well developed eyes. Magnification: 100X.*

Dr. Lanna Cheng



Scanning electron micrograph of dentition of the California marine snail Acanthina spirata. *The five-cusped central tooth is used to remove enzyme-softened shell of prey to bore a hole. Scythe-shaped marginal teeth tear flesh of prey. Magnification: 450X.*

George Hemingway

Marine Life Research Group

Marine Life Research (MLRG) has carried on a wide variety of research during the past year in many fields: varved sediments and their relationship to the regional environment during the past few hundred years; the study of krill, or whale food, off Chile and Peru and other euphausiids off Mexico and in the California Current; sablefish and rattail feeding habits and spawning off San Diego, phytoplankton ecology in the Central Gyre of the North Pacific; the specialization process in copepods and some mating observations.

Other fields researched were the marine insect *Halobates;* deep circulation in the Pacific Ocean; El Niño event off South America; seasonal variation of the California Current; decreased solar irradiance along the coast of California and its relationship to coastal upwelling; surface currents in the Gulf of California; eddies in the California Current; and instrument development.

MLR participated in CalCOFI (California Cooperative Oceanic Fisheries Investigations) studies during the year using R/V *Alexander Agassiz* and covering the California Current with patterned cruises. With the increased interest of Mexico in its marine resources, the Instituto Nacional de Pesca participated in CalCOFI cruises with its ship, *Alejandro de Humboldt*. Students from the marine college of the University of Baja California, Escuela Superiór de Ciencias Marinas, participated in each *Agassiz* cruise during the CalCOFI year, and on *Agassiz* cruises to the Gulf of California.

Following are brief reviews of research conducted by various members of MLRG.

Serial accumulations of sediment and microfossils resolvable to approximately annual scale (*i.e.,* varves) are a unique source of information on the regional environment of the depositional basin. Recent progress in the project, carried out under John D. Isaacs' direction and by Andrew Soutar, Dr. Stanley A. Kling, and Peter A. Crill, has been aimed particularly at reconstruction of climatic-ecologic conditions from the present to past several centuries off southern California. Historical records are being used to refine the calibration of the sedimentological and micropaleontologic tools. This has taken the form both of extraction of pertinent environmental indices from voluminous data collected from many locations, and of formulation of statistical-mathematical techniques for handling the comparisons among various environmental and stratigraphic measurements. Air and sea temperature and rainfall indices representing the California Current region have so far been compiled.

The unaltered rainfall time-series for the Santa Barbara Basin area show departures from the median not different from a random series, but groups of rainfall anomalies appear related to fluctuations in sediment accumulation as measured by varve thickness. Furthermore, the varve thickness of any year is related to the rainfall of the previous years, to a decreasing degree back in time. With a time constant of four years, a measure of the length of time during which information resides in the system produces excellent correlation between rainfall and sediment accumulation. Similarly, tree growth as measured by ring thickness is related to rainfall, but with a lag of 2.5 years. Thus, the rate of sedimentation in the Santa Barbara Basin senses fluctuations in rainfall and records the time necessary for passage of a single year's rainfall through the drainage basin.

Temperature indices for air and seashore water stations are correlated with each other over the entire California region and so permit the compilation of a regional temperature index. The resulting time series is well correlated with adjacent and more northerly 5-degree-square estimates of sea-surface temperature anomalies of Dr. Jerome Namias, and its pattern is not unlike the temperature record for central England given by Dr. H. H. Lamb, University of East Anglia, England. Temperature is indirectly

recorded in sediments via its effect on the fossil biota. Initial results from diatom and radiolarian data indicate correlation between certain species or groups of species and temperature (as well as other environmental variables).

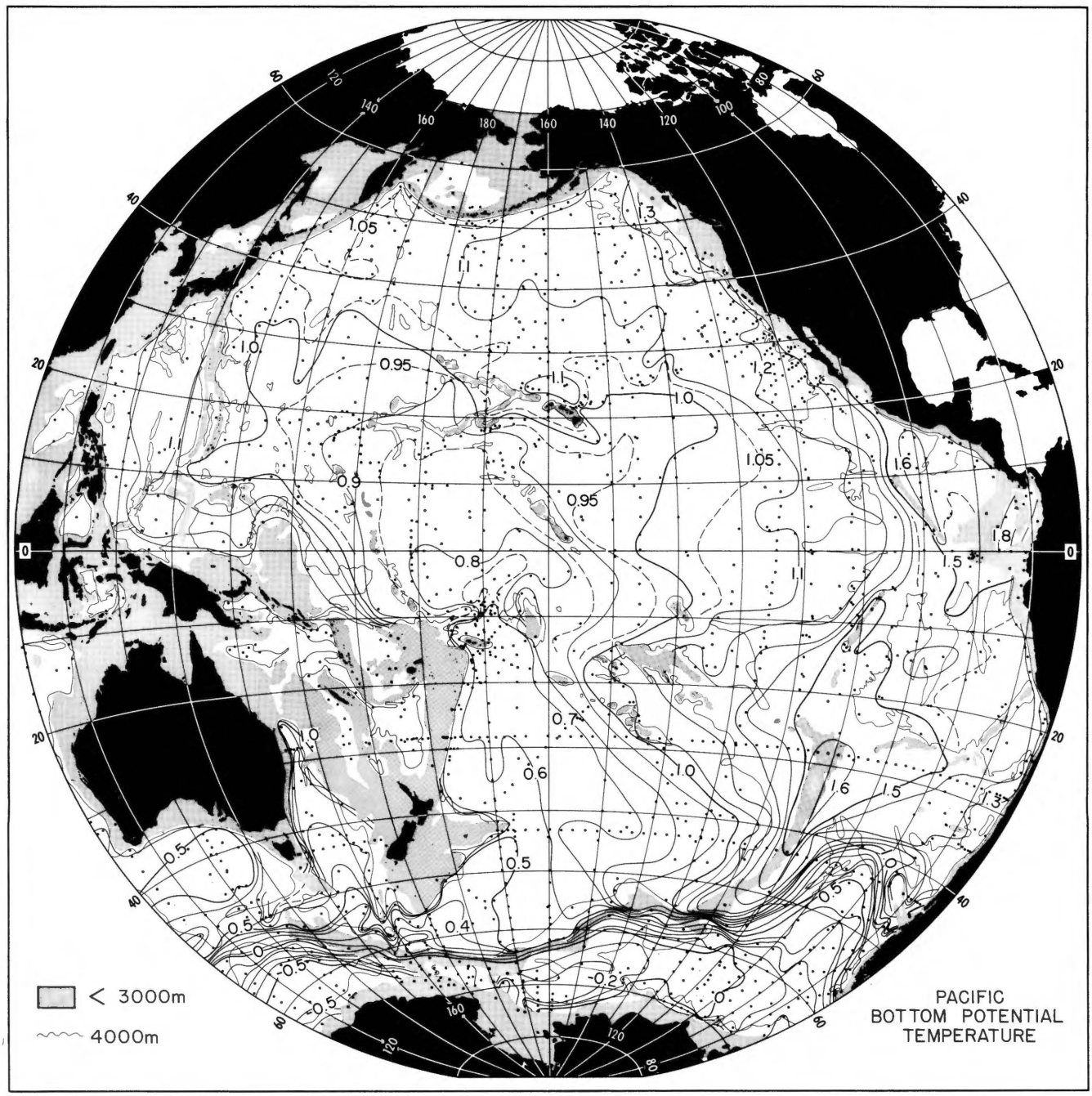
Estimates of pelagic fish biomass derived from scale counts in anaerobic sediments off California indicate high abundances centering on 1895 and 1860, followed by an anomalously low abundance for the last 40 years. A cursory comparison of the fish biomass with the temperature index suggests that highest productivity during the past century-and-a-half occurred during the coldest period, but there is as yet no statistical support for a direct relation between fish abundance and temperature. Curves resulting from diatom and radiolarian analyses also resemble fish biomass estimates, thus suggesting that organic productivity through the food chain (phytoplankton-zooplankton-vertebrates) is recorded in anaerobic sediments.

Aspects of growth, development, and population ecology of the euphausiid crustaceans are being studied by Dr. Edward Brinton and Margaret D. Knight. Known as krill these large zooplankton animals are being increasingly considered in many parts of the world with respect to their potential as a harvestable resource. During the Krill Expedition to the west coast of South America, Tarsicio Antezana, a Scripps graduate student from Chile, collected material for such a study of the abundance in the Peru-Chile Current. Also examined was the vertical distribution of zooplankton off Mexico and in the eastern tropical Pacific; this confirmed the existence of widespread adaptations by euphausiids to mid-depth waters that are almost devoid of oxygen.

Depths at which mid-oceanic plankton penetrates into the easternmost tropical region within the system of easterly countercurrents were also examined, with the intrusions proving to be by species persisting at discrete depths, not belonging to the vertically migrating community.

Dr. Brinton also is studying the California Current euphausiids, to investigate the effect of intermittent warm years (*e.g.*, 1958-1960) — as com-

Map shows distribution of near-bottom potential temperature of Pacific Ocean, in Celsius degrees. Areas less than three-km deep are shaded.
Arnold M. Mantyla



pared with the more typical cooler years — on the development and maintenance of the predominant temperate populations off southern California, considering particularly localization and seasonality of their recruitment and survival.

Identification of the larvae by Knight has contributed to the description of the distributional range of the species, in some areas represented in samples only by their larval forms, and to the systematics and phylogeny of the group.

Cursory examination by Tetsuo Matsui of sablefish *(Anoplopoma fimbria)* and rattails *(Coryphaenoides acrolepis)* of southern California indicates that the sablefish fed on larger mid-water and benthic organisms, while part of the rattail food appeared to be smaller animals in the sediments. Although sablefish have been observed resting on the bottom, their lack of a swimbladder probably makes them less efficient at hovering and rooting in the sediments than the rattail, which has a swimbladder. A sample of sablefish recently caught at the Coronado escarpment had a near 1:1 sex ratio. This contrasts with prior samples which were mostly females. The recent sample also seems to indicate that the males are probably found along the slopes at depths shallower than are normally sampled and that the distribution of sexes of sablefish may follow a similar pattern to that of the rattail.

Opening-closing net samples taken at discrete depth intervals from near surface to near bottom in the San Diego Trough show that the larvae and juveniles of the searsids *Sagamichthys abei* and *Holtbyrnia* n. sp. occur at depths of 300-800 m and at very low oxygen values (0.2 to 0.8 ml/l). This agrees with previous estimates made for these species from samples collected in open 3.0480-m, Isaacs-Kidd mid-water trawls and lends support to estimates made on other species of the family from open 3.0480-m IKMT samples.

Phytoplankton distributions and ecology in the Central Gyre of the North Pacific have been continued by Dr. Elizabeth L. Venrick, together with Dr. John R. Beers, graduate student John F. Heinbokel, and Edward H. Renger. They have completed data analysis for a shipboard study of the biological changes that occur during incubation of a natural population for routine C^{14} experiments.

Other completed research is enumeration of a series of samples collected to investigate the effect of wind-driven turbulence on the vertical stratification of flagellated and non-flagellated phytoplankton.

Drs. Abraham Fleminger and Kuni Hulsemann continued their consideration of speciation processes in representative epiplanktonic copepods with biogeographic-phylogenetic studies on calanid and pontellid species.

Among the Calanidae, they concentrated on the ecologically and economically important populations of the *Calanus finmarchicus-Calanus helgolandicus* complex. One of both kinds is represented in the mixed layer by regional populations in all highly fertile temperate to subpolar regions of the world's oceans and seas. Within their respective habitats, these herbivores usually dominate the zooplankton biomass, and their biological properties and population dynamics are of considerable interest to plankton ecologists. Geographical overlap of the breeding stocks of different species and unsatisfactory characterization of adults of most species, as well as virtually all juveniles, has, however, impeded and compromised both field and laboratory studies. Despite much past effort, confusion and controversy over the identity of the described species and subspecies among taxonomic specialists have not abated.

Using representative global collections and adding integumental organs to the list of potentially diagnostic characters, Drs. Fleminger and Hulsemann were able to distinguish objectively the reproductive isolated populations falling within the complex.

They determined that the finmarchicus-helgolandicus complex is represented in the world's oceans by three morphologically differing groups of closely related species comprising a system consistent with biogeographic, oceanographic, and ecological facts. The progenitors of these groups probably radiated independently and recently; *i.e.*, certainly after middle Pliocene.

One of three phylogenetic lineages occupies the boreal-to-polar latitudes of the Northern Hemisphere with three of the species appearing in the North Pacific; another is cool temperate to boreal in the Northern and Southern Hemispheres; the third is warm temperate to temporate in both hemispheres. The evidence unequivocally supports elevation of Brodsky's (K. A. Brodsky, biologist with the Zoological Institute, Leningrad) subspecies to the rank of species, which affects the status of the most abundant copepod in the California Current, *Calanus californicus* Brodsky, and unmistakably points out the source of much secondary production in the California Current region.

Published observations on mating in calanoid copepods are few in number. While he was examining live plankton during a CalCOFI cruise (7505-J), Dr. Fleminger noted that a sample of *Labidocera jollae* increased its level of activity and took on the appearance of a highly agitated mating swarm. A mating swarm of *Labidocera jollae* was found. It became possible to follow visually in about 30 cases, the initial capture of the female by the male and to transfer the mating pair to a stereomicroscope. Here were observed the means by which the mating pair stayed in copulation, their behavior during spermatophore ejaculation, and the handling of the spermatophore up to its attachment to the female. In all, microscopic observations were made on about 30 pairs. The observations confirmed previous thoughts on the process obtained by reconstructing patterns from females carrying spermatophores. Attempts to observe mating in *Labodocera trispinosa* have not yet been successful, but they will continue as time permits in order to answer questions concerning the nature of the reproductive barrier existing between the two species that share similar geographical and ecological ranges off California and Baja California.

Studies by George T. Hemingway centered on various aspects of feeding of the California marine snail *Acanthina spirata,* a predator upon barnacles, mussels, and other immobile occupants of the rocky intertidal zone. His work included descriptive morphology, cinematographic analysis of feeding, and isolation and assay of a prey-paralyzing toxin.

Research on the oceanic insect *Halobates* by Dr. Lanna Cheng has shown that of the 40 species known in the genus, at least five are pelagic; they are found generally between the latitudes of 40°N and 40°S, exclusively in the high seas. Analyses of data based on collections from the Atlantic Ocean have shown that there is probably no distinct breeding season for these ocean-skaters. They suck the body contents of plankton organisms such as fish eggs, fish larvae, copepods, amphipods, and euphausiids, which become temporarily trapped, or are found primarily at the sea-air interface. They themselves are preyed upon by sea-birds and surface-feeding fish.

Halobates is also unique among marine organisms in occupying a two-dimensional environment in the ocean. Since it lives at the sea-air interface, does not possess wings, and cannot fly, its distribution must be determined predominantly by interactions of surface winds and currents. Thus the presence and absence of specific *Halobates* in a certain area or during a particular season may indicate certain physical phenomena of the ocean surface.

A study of the deeper circulation of the Pacific Ocean based upon the relative geostrophic flow at the sea surface, 1,000 m, 2,000 m, 2,500 m, and 3,000 m was completed by Joseph L. Reid and Dr. Robert S. Arthur. The study presents a qualitative but coherent scheme of circulation for the intermediate, deep, and bottom waters of the Pacific, and suggests that the poleward flow beneath the eastern boundary currents is much wider and deeper than had been supposed. The study also reveals a poleward migration of the subtropical gyres at increasing depths.

Parallel to this, Arnold W. Mantyla has made a new map of the potential temperature at the bottom of the Pacific. He has discussed the transformation (in the North Pacific) of the cold bottom water into deep water that returns southward above the bottom water, with a maximum in hydrostatic stability observed between them near the Hawaiian Islands and with such weak vertical gradients of potential temperature that two *in situ* temperature minima are observed there, one in the deep water and one in the bottom water.

Reid and Mantyla studied the seasonal variation of the California Current off Baja California. They reviewed the seasonal flow in terms of the density field, the geostrophic readjustment of the field to the varying flow, and the consequences in sea elevation both offshore and along the coast, where the results were confirmed by tide gauges.

From February through April, a University of Hawaii expedition was carried out off the coasts of Ecuador and Peru in response to a prediction in October 1974 that anomalously warm waters termed El Niño might appear in this region in early 1975. During the first cruise, Dr. William C. Patzert, of Scripps, observed that trade winds were almost nonexistent and a large, but shallow, movement of warm, low-saline water across the equator was observed, as well as depression of the thermocline and cessation of upwelling along the equator and along the coast of South America, confirming the start of El Niño condition. During the second cruise, trade winds had returned and cooler conditions normally expected were quickly returning, indicating the end of the short El Niño event observed earlier.

Decreased solar irradiance during the summer months near the coast of southern California is related to coastal upwelling. It has been calculated by Sargun Tont that if monthly averages of percent of possible sunshine were the same in June as in January, the sea surface would receive 37 langleys per day more than it ordinarily receives. Consequently, the sea-surface temperature is 1.1°C lower in June than it would have been otherwise.

Small cyclonic and anticyclonic eddies in the California Current are being studied to determine their distribution, the area of concentration, and

their duration. According to the *CalCOFI Atlas* of relative geostrophic flow, the cyclonic and anticyclonic eddies are about equal in number. They are scattered throughout the current, with some concentration west of the channel islands off southern California, south of Guadalupe Island, and north of Punta Eugenia.

The Gulf of California surface currents have rarely been measured, yet this region is well known for its very strong tidal currents. Drift-bottle data from 11 cruises, Earth Resource Technology Satellite (ERTS) satellite pictures, tidal measurements, and other measurements have been examined by Richard Schwartzlose and José Luis Granados G. (Instituto Nacional de Pesca, Mexico). These data indicate a general pattern of southward flow in winter throughout the entire gulf, a northward flow in summer south of the islands of Tiburón, San Esteban, and San Lorenzo, and some northward flow into the northern gulf, with also some eddy circulation. During the spring and fall, the flow is less systematic. There are also indications that the surface waters between the northern and southern gulf are not mixing as much as had been concluded in the past. The islands near the middle of the gulf, and the shallow sills, greatly restrict the amount of exchange that can take place.

Several instruments have been under development for use in MLRG research. Sediment traps that collect the detrital material that falls to the ocean floor are being tested by Soutar and Daniel M. Brown. These traps are to be deployed for periods of one to six months. Improved traps by Brown and Meredith H. Sessions will allow use on open and closing trawls and nets and for long-term release of instruments that will be left in the ocean up to one year.

An improved light-weight acoustic release is also being tested. A near-surface current meter is under development by Sessions, and substantial testing of it has been accomplished. Present tests indicate that a bidirectional linear cosine response has been obtained.

The free-vehicle current meter, used for deep, near-bottom research, is being modified for digital recording and may be moored at a significant distance off the bottom with moderate tension. A system has been developed and is now in use to allow digital recording via punched paper tape of biological samples as they are sorted. A number assigned to each species is punched on the tape as it is sorted and counted. These data are suitable for direct reading by an IBM 1800 computer.

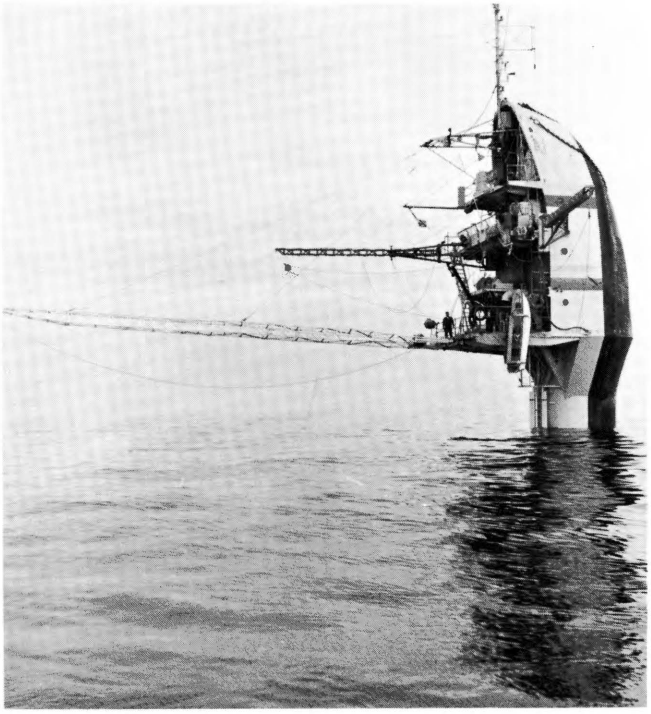
Marine Physical Laboratory

Understanding the effects of the ocean and its interfaces on the generation, propagation, and application of acoustic energy continues to be the principal goal of the Marine Physical Laboratory (MPL). The research areas include studies of the variation in sound propagation caused by oceanic parameters, signal processing, observation of oceanic phenomena and the ocean bottom with acoustics, and development of ocean technology.

Although not part of the direct research program, advisory activities of the MPL staff require and deserve considerable effort in providing expertise to various scientific societies and federal agencies. In this capacity, senior MPL staff members have interacted with the National Academy of Sciences, the National Academy of Engineering, the National Science Foundation, the U.S. Atomic Energy Commission, UNESCO, the Acoustical Society of America, the American Geophysical Union, the Institute of Electrical and Electronics Engineers, the Marine Technology Society, and various committees of the U.S. Navy.

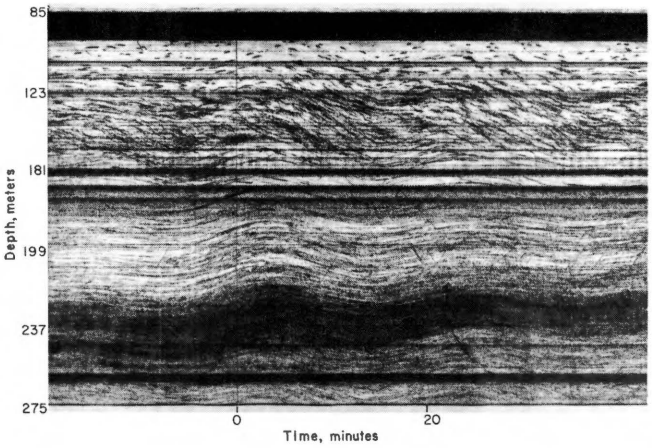
Dr. Fred N. Spiess, director of MPL, has been on leave this year as a member of the scientific liaison staff of the Office of Naval Research branch office in London. This has given him an opportunity to observe developments in ocean science and engineering in western Europe. In Dr. Spiess's absence, Dr. Victor C. Anderson has served as acting director.

The end of fiscal 1975 also marks the official "retirement" of two MPL scientists. Prior to joining MPL in 1958, Victor Vacquier had developed new instrumentation and techniques for measuring magnetic fields, including the magnetic airborne detector (MAD). At MPL, he developed the three-component, fluxgate magnetometer and the proton precession magnetometer that were used for mapping the total magnetic field at sea. With this instrumentation, Vacquier observed magnetic anomaly lineations and measured the large fault displacements indicated by these anomaly patterns. These data were vital to the acceptance of the subsequent sea-floor-spreading concept. Later work included electromagnetic induction studies of the electrical conductivity structure in the earth; these showed the transition of this structure from the continent to the sea floor. More recently, Vacquier has been studying terrestrial heat flow, both at sea and on land.



R/P FLIP at sea, with three suspended booms utilized during internal-wave-observation program.

Marine Physical Laboratory

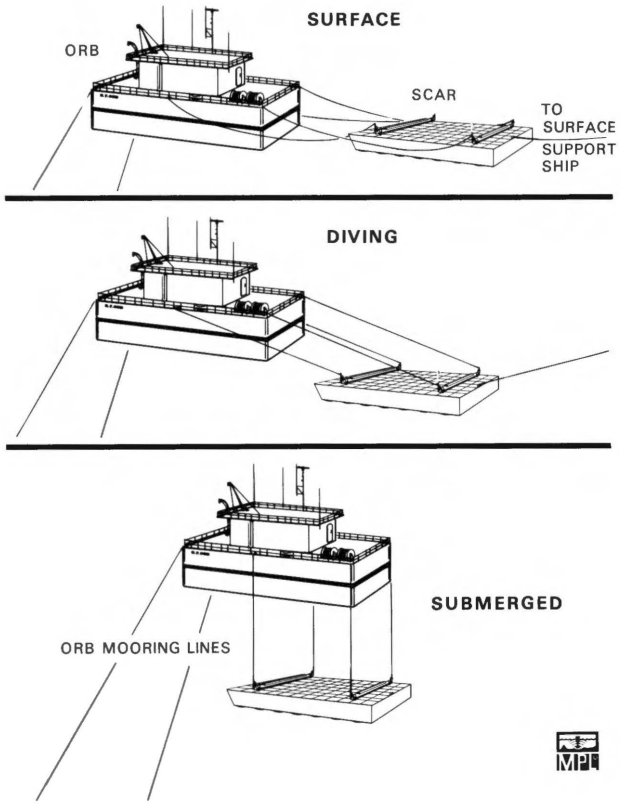


Distribution of biological layering as observed acoustically with an 87.5 kHz sonar system. Layers appear to oscillate at typical, internal-wave period. Major portion of deep scattering layer is at 240 m. Current speed relative to FLIP is about 0.3 kt.

Marine Physical Laboratory

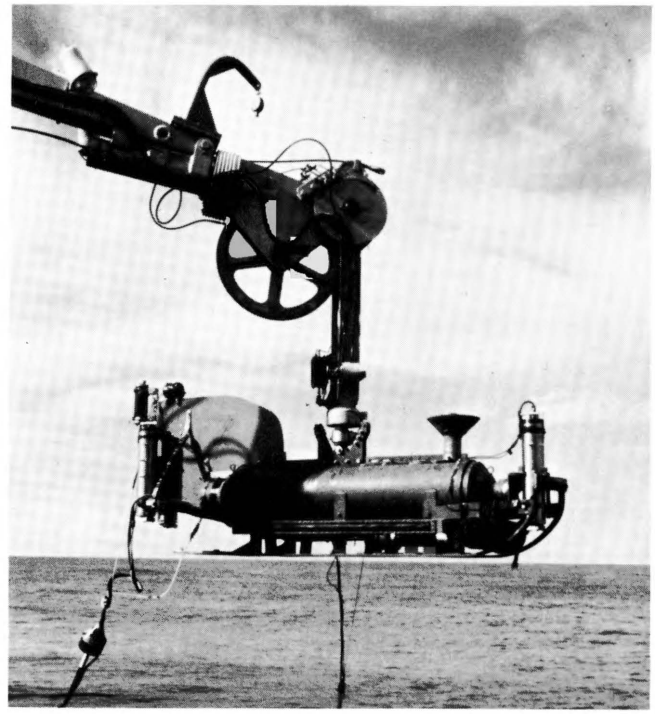
The second "retiree," Dr. Russell W. Raitt was a member of the University of California Division of War Research, and was a "plank-owner" in the founding of MPL in 1946. His work during that time covered the reverberation of sound in the ocean; reflection of sound from the ocean surface and bottom; the generation, transmission, and attenuation of explosive impulses in the sea; participation in the discovery of the deep-scattering layer. In subsequent work, Dr. Raitt continued to develop and apply seismic reflection and refraction techniques in studying the crustal layers and the upper mantle in the ocean basins, marginal seas, and trenches of both the Pacific and Indian oceans. His latest work has been the measurement of velocity anisotropy in the ocean basins.

Dr. Anderson and W. Robert Cherry have been working on a project to



Artist's conception of diving procedures used for Marine Physical Laboratory's Scattering Array (SCAR) and for its suspension below R/P ORB.

Marine Physical Laboratory



The Deep-Tow instrumentation system, above, development of which began in 1960 by Marine Physical Laboratory, has evolved into a versatile, sophisticated, instrument suite for direct observation of the ocean floor at depths of up to 7,000 m.

Marine Physical Laboratory

describe the directionality of noise at the sea surface in the frequency range of 1-4 kHz. The experimental hardware consists of an array of 48 hydrophones mounted on FLIP's hull. This array can be trained electronically in the horizontal and vertical directions, and can be focused to study a patch of the ocean surface while simultaneous measurements of wind speed and surface wave activity are recorded. From these data, three-dimensional distributions of ambient noise near the air-sea interface are obtained for varying conditions of the sea surface. By monitoring the sea-surface patch, one can observe not only individual surface waves, but also the passage of wave packets.

Brett Castile, a research assistant, and Dr. Anderson have assembled a system for studying acoustic volume reverberation of multiple frequencies from 20 to 800 kHz. At higher frequencies, one may observe scattering from small organisms. The very fine resolution of this system will allow a detailed study of the spatial distributions of these scatterers over a large range of frequencies. Thus, the large-scale features of the deep-scattering layer, as well as the fine structures of regions of similar gross properties, may be observed.

The development of signal processing continues to be an integral part of MPL research. With the rapid advance in computer technology and the more powerful analysis techniques that have been made available by these advances, it becomes possible to suggest new, more effective methods for dealing with acoustic problems. One such application is the Sic Transit Sonitus project, a plan for the passive detection of the passage of sound sources. Dr. Philip Rudnick assisted in the design of this experiment, and helped define the statistical parameters that are associated with the transit detection. Richard A. Harriss manages the data collection from the oceanic installation and the data analysis. From this analysis the distribution of acoustic energy within the frequency range of 0.6-10 kHz will be identified.

The Remote Underwater Manipulator (RUM), operating from R/P ORB, was used for a four-day project in support of the Sic Transit Sonitus project. The vehicle was used to locate, recover for repair, and reinstall an acoustic sensor package on the sea floor at a depth of 500 m.

In a continuing effort under a contract with the Shell Pipeline Research and Development Laboratories, MPL is assisting with the development of the Shell Pipeline Repair Vehicle (SPRV). This work is an extension of the technology that was developed for RUM operations, and is concerned mainly with umbilical cable design, power transmission and control, cable telemetry, vehicle sensors, and acoustic systems.

Dr. Anderson, Daniel K. Gibson and their group have been developing a deep-submerged, large-aperture, acoustic, receiving array. This will be used to measure the statistical directional properties of the background noise field in the ocean. The array will be towed to sea, submerged, and suspended from ORB to depths of the oceanic sound channel. The data will be processed and displayed aboard ORB. The ocean technology and signal processing problems of this project represent an advance in the technology that was developed by MPL for use of the Deep Tow, the Remote Underwater Manipulator, and the Scattering Array.

Dr. Theodore Birdsall, University of Michigan, has spent part of his sabbatical at MPL, working on various aspects of signal-processing techniques in order to acquire information from explosive shot data. These data are being reduced to provide information on acoustic propagation loss in the ocean as a function of both depth and range.

Last year Dr. Raitt and other members of the MPL seismic refraction group, with graduate students John A. Orcutt and Bruce R. Rosendahl, cooperated with Dr. LeRoy M. Dorman in a geophysical study of the axis of the East Pacific Rise, on Siqueiros Expedition, to determine how new lithosphere is formed at a spreading center. In the plate-tectonic theory, new lithospheric material (basement, crust, and upper mantle rocks) is formed at spreading centers along oceanic rises, and gradually moves away from the rises as it ages. The manner of generation of these rocks from the upward-moving magma has, however, been a matter of some dispute. Results of the Siqueiros experiment, in which seismic refraction lines were shot to be received at seismographs on the ocean bottom and sonobuoys at the ocean surface, along lines carefully placed parallel to the axis of the rise, have given new evidence concerning the origin of the lithosphere. An elongate zone of material with a low velocity for seismic waves lies in the lower part of the crust along the axis of the rise, but does not appear only tens-of-kilometers off to the sides. This zone is apparently a magma chamber, from which the layers of the sea floor are formed by upward extrusion and downward differentiation of the magma. Results inferred from the refraction studies were confirmed by analysis of dredged rock samples.

In order to handle the multireceiver seismic lines from this expedition and from work in the Indian Ocean, Dr. Raitt developed a new method of delay-time function analysis of the travel-time data.

Dr. George G. Shor, Jr., and William Whitney have been working on methods of measuring the efficiency of the energy transmission of compressional waves through the sea floor in the ultrasonic range, between 4 and 32 Hz. Analysis of data taken on Leg 1 of Eurydice Expedition, at stations near San Diego, has shown that the bottom-transmitted sound begins to become a significant part of the total energy transmission for frequencies below about 6 Hz. Theoretical studies to date indicate that a large proportion of the transmission at these frequencies takes place deep in the crust, rather than in the near-bottom material.

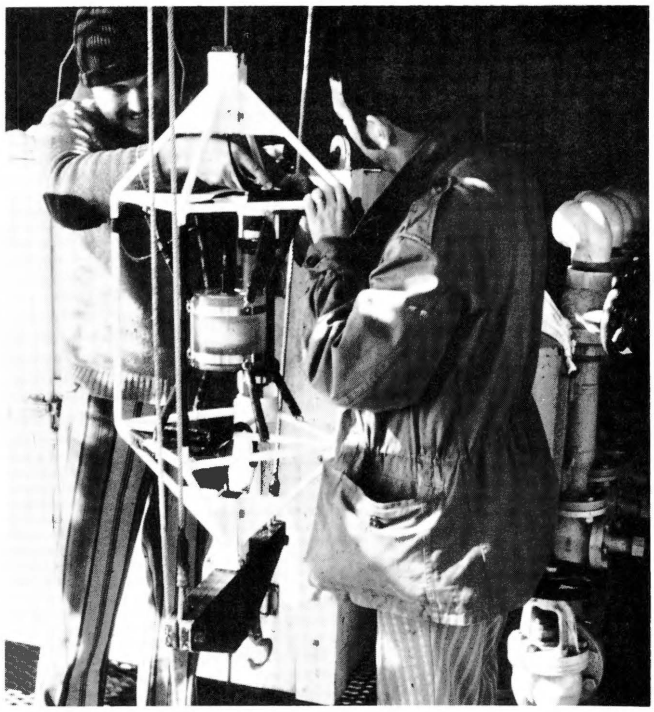
Extensive field work was done on later legs of Eurydice Expedition, in cooperation with Scripps geologists of the Geological Research Division (GRD); more extensive reports may be found in the GRD section. Dr. Shor, Rosendahl, and other members of the seismic group worked with Dr. Edward L. Winterer in structural surveys of the area of the Canton Trough (a deep rift along the equator in the central Pacific). These studies are intended to extend the work of the Siqueiros Expedition to much older crust; extensive dredging was carried out to obtain samples of the rocks being studied by geophysical means. Dr. Raitt and Marilee Henry participated with Dr. Joseph R. Curray and Dr. David G. Moore, the latter of the Naval Undersea Center, San Diego, in geophysical studies of the Andaman Sea and of the Indian Ocean southwest of Indonesia, as part of a continuing study of sedimentation along the margins of the Bay of Bengal. On the final leg of Eurydice, graduate student L. Dale Bibee worked with Dr. Winterer and Dr. N. Terence Edgar in additional refraction studies of the equatorial carbonate belt.

Dr. Leonard N. Liebermann has been developing a displacement hydrophone for reception in the infrasonic frequency range of 3-30 Hz. At these very low acoustic frequencies, it is expected that this hydrophone type will be more sensitive than the conventional pressure hydrophone. Because displacement hydrophones are not available commercially, MPL has developed its own instruments and the calibration facilities and procedures with which to test them. Work is presently under way for a direct comparison between the two types for bottom-mounted hydrophones in shallow water. The installation will be approximately 2 km offshore from Scripps.

Dr. Frederick H. Fisher is involved with one project using a vertical array of 20 hydrophones, suspended from FLIP, to discriminate among the multipaths of sound travel in the ocean. By observing the arrivals of an acoustic signal that has traveled along several paths, scientists hope that they will be able to trace backward to arrive at the range of the sound source. Another of Dr. Fisher's projects is his continuing work on the effects of pressure on electrical conductance of electrolytes found in seawater, especially those involved in sound absorption. Dr. Fisher and Frank Phelan have been working with acoustic signals that are received after bouncing off the ocean bottom. The object of the experiment is to determine whether small-scale bottom topography alters the azimuthal bearing of the signal reflection. For the experiment as presently structured, bottom-bounce errors caused by topographic changes on the horizontal scale of 200 m have been observed. A by-product of this research has been the observation of biological layering in the water column. The illustration shows the vertical distribution of sound scatterers that were observed with this 87.5 kHz acoustic source.

Under the guidance of Dr. Anderson, Dr. G. Thomas Kaye's group has been completing the construction and operational check-out of a large acoustic array for observing the density fine structure of the upper 400 m of the water column. The Scattering Array (SCAR) has dimensions of 15x15x1.8 m and a weight-in-air of nearly 64,000 kg. At sea, SCAR is suspended at a depth of 20 m below R/P ORB. The array consists of an 8-kW sound-source and 128 hydrophones facing downward. With real-time signal processing, this group will be able to distinguish between layered (density structure) and discrete (biota) reflectors. This remote-sensing technique can then provide information of density fine-structure evolution, internal wave activity, and acoustic scattering by water-density structure. Biological layering has also been observed with this device at frequencies of 8 and 16 kHz. From these observations it has been noted that the biota are stronger acoustic reflectors than the thermocline immediately beneath the wind-mixed layer.

Vernon P. Simmons, with Dr. Fisher as his advisor, has completed his dissertation work on low-frequency sound absorption in the ocean. Laboratory measurements using spherical resonators have confirmed that increased sound absorption at low frequencies is caused by the presence of boric acid in seawater. It is remarkable that such a small amount of boric acid, around 0.0004 moles/liter, can produce such a large effect. An understanding of this chemical-absorption loss makes it possible to examine other propagation-loss mechanisms at low frequency.



Lewis P. Berger, at left, and Robert J. Truesdale add hydrophone element to vertical array during FLIP cruise.

Marine Physical Laboratory

Sea-floor studies were conducted by Drs. Spiess, John D. Mudie, and Carl D. Lowenstein, using the Deep-Tow instrumentation system. Development of this package was begun in 1960, and it has evolved into a versatile, sophisticated, instrument suite for direct observation of the ocean floor at depths of up to 7,000 m. The Deep Tow has been used worldwide for various research programs. Some of these programs have included the determination of environmental limitations of sea-floor search and navigation, studies of sea-floor geological and physical oceanographic processes, studies of sea-floor acoustic properties, and actual search and mapping operations.

Dr. Peter F. Lonsdale has used the Deep-Tow instrument package for geophysical and geological studies in the tropical eastern Pacific. His purpose was to examine tectonic processes that are associated with active spreading centers. Bottom currents of more than 30 cm/sec were measured and related to abyssal sedimentation and erosion patterns. The movement of a field of abyssal sand dunes was discovered by mapping the field twice, during a two-year period, with a side-looking sonar.

Robert C. Tyce has developed a quantitative 4-kHz seismic profiling system as part of Deep Tow. It has been used to obtain more detailed information on sound absorption characteristics of various ocean-bottom types. Initial results from data collected near Samoa and near San Diego indicate that substantial variations in sea-floor acoustic reflectivity occur over small horizontal distances. Attenuation measurements and sediment physical property analyses were also made. In the coming year, a joint cruise with researchers from the Woods Hole Oceanographic Institution in the North Atlantic is planned.

Using hydrophone arrays suspended from R/P FLIP, Dr. Gerald B. Morris and his group have conducted a major acoustic study 700 km off the coast of southern California. The investigation deals with the effects of geometrical shadowing of seamounts on acoustic propagation. The analysis of these data is continuing. Also, the group has been studying ambient noise in the ocean in the frequency range of 10-1,000 Hz. This study is particularly interested in the correlation of wind speed and hydrophone depth with noise level.

Dr. Robert Pinkel and his group have continued an extensive internal-wave measurement program that has been developed at MPL. Profiles of temperature versus depth are taken repeatedly from FLIP by "yo-yoing" thermistors. These measurements yield isotherm depth fluctuations, which then describe the space-time variability of the internal-wave field. From this it has been noted that linear internal wave dynamics appear to govern

the larger scale motions in the upper 440 m of the water column. Future measurements will include a high-resolution, density-profiling system using conductivity sensors.

Dr. Robert A. Rasmussen has been investigating the problem of placing a sonar system in a small, self-propelled vehicle. If this platform has physical dimensions that are comparable to an acoustic wavelength, undesirable effects are encountered that can be caused by mechanical vibration, sensor enclosure, and sound scattering. In order to evaluate these effects, actual test bodies have been constructed and at-sea tests have been performed. It is planned that these tests will be continued to evolve an appropriate sensor system design.

With Dewitt O. Efird as officer-in-charge, R/P FLIP was used for seven operations in the Pacific. Terry G. Hoopes serves as officer-in-charge aboard R/P ORB, which participated in six expeditions.

At the off-campus Balboa Avenue Building, research on acoustic properties of materials and low-frequency sound absorption in the ocean is being conducted. Also at this location MPL operates the Southwest Regional Calibration Center, a division of the National Oceanographic Instrumentation Center of the National Oceanic and Atmospheric Administration. The center has been involved with the calibration of oceanographic instrumentation for governmental and nongovernmental research, concentrating primarily on STD/CTD (Salinity-Temperature-Depth/Conductivity-Temperature-Depth) equipment, mechanical BTs (bathythermographs) and laboratory salinometers. During the past year, a pressure-cycling tank was added as an extension of the facility's capabilities.

The performance requirements and physical dimensions of some instrument packages provide a considerable challenge in ocean engineering. Deep Tow, for example, can be "flown" from a surface ship at ranges as close as 10 m off the sea floor. SCAR is suspended from R/P ORB, but its motion is decoupled from the sea surface. RUM can sample the benthic ecology of the sea floor with meter-scale accuracy in ocean depths of 2 km.

Neurobiology Unit

Dr. Theodore H. Bullock has recorded brain waves from octupuses, and learned that they are more similar to those of vertebrates than to those of other invertebrates. With Dr. Robert C. Eaton and Thomas G. Uter, he is estimating the domains of coherent activity as a function of frequency in different groups. Dr. Eaton has recorded the electrical activity of the single nerve cell in the brain of 3-mm fish larvae that commands the startle response. This record permits analysis of sensory systems involved in this behavior and the sequence of development of the different types of synaptic junctions on a nerve cell. Together with Drs. Rocco A. Bombardieri, Jr., and Dietrich L. Meyer, Dr. Eaton has examined the startle-response behavior of several species of fish by high-speed photography, in order to facilitate correlation with the habit of life and the structure of the brain.

Dr. Albert S. Feng is studying the pacemaker neuronal mechanisms of a social behavior, the jamming-avoidance response of the weakly electric fish *Eigenmannia*. The great advantage of this material is in permitting the visualization of minute synaptic inputs to pacemaker neurons. He has also found that the temperature effect on this social behavior is to enhance its magnitude at higher temperature; the tuning of the receptors is evidently shifted in the same way with temperature as the electric organ pacemaker.

Dr. Konstantin Behrend has succeeded in finding and characterizing two types of single-unit electroreceptors, sensitive to feeble AC electricity in the water, in the African electric fish *Gymnarchus*. In studies on the brain, he is measuring the effect of jamming on the ability of single nerve cells to detect objects by electroreception; this requires on-line computation and a microelectrode in the cerebellum.

Dr. Meyer has studied the visual-postural control mechanism in fish, comparing the dorsal light response among species and a second mechanism that enables certain fish to keep their ventral side toward a vertical wall when swimming close to the wall. The results of lesions and unit recordings are interpreted as showing the pathway that mediates visually guided postural control runs through the tectum, and the visual-vestibular integration is related to structures in the rostral tegmentum. Using the shark facility of the Neurobiology Unit, Dr. S. O. E. Ebbesson, University of Virginia, and Dr. Meyer are studying visual and vestibular pathways in the brain of elasmobranchs by methods of experimental anatomy.

Dr. G. David Lange, continuing his collaboration with Drs. Peter H. Hartline and Ann C. Hurley, has extended the study of the neurophysiology of vision in cephalopods. This includes linear systems analysis of squid and octopus electroretinograms and correlations with quantitative measures of behavior.

Research programs were also conducted by several UCSD graduate students in neurosciences:

Howard Krausz has extended his development of the techniques of analysis of sensory systems by band-limited, white-noise stimuli.

David W. Jensen is studying the processes in recovery of equilibrium in animals that have lost the organ of balance on one side. By recording from single cells in the vestibular nuclei of the brain stem, Jensen will classify the multisensory interactions, especially with vision, skin, and joint senses, as they experience compensation for the lesion.

Eric I. Knudsen is studying the higher order processing of electroreceptive input in the midbrain of siluroid fish. He has uncovered effects of electric field magnitude, frequency, geometry, and movement on the activity of single cells and groups of cells. He has characterized the multimodal interactions, especially of visual, auditory, and mechanoreceptor inputs converging with the electroreceptor input.

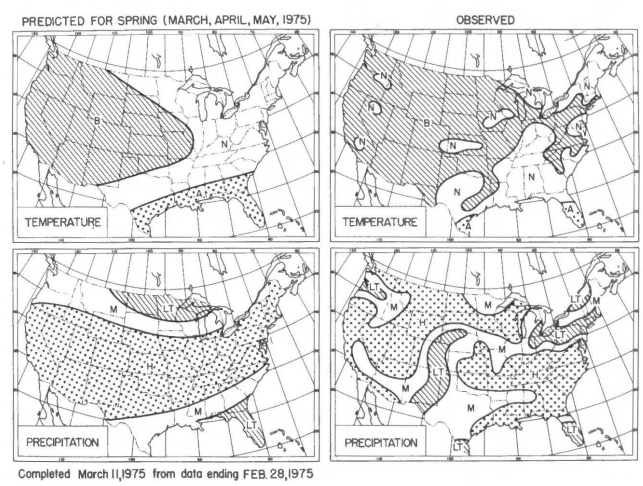
Terry A. Viancor has applied the white-noise stimulus technique to the analysis of response of electrosensory neurons in *Eigenmannia,* and has classified response-latencies to pulsed electric fields in central neurons of the lateral-line lobe of the brain, as well as the frequency-response thresholds of these and higher order cells.

NORPAX

NORPAX (North Pacific Experiment) is a multiinstitutional program sponsored by the National Science Foundation and the Office of Naval Research to study the large-scale fluctuations in the thermal structure of the Pacific Ocean from 20°S to 60°N and its relations to the overlying atmosphere. Achievement of this goal should eventually lead to the ability to predict the thermal structure of the upper layer of the Pacific Ocean and to improved weather/climate prediction for both the northeast Pacific Ocean and North America. Attainment of this goal is clearly years away.

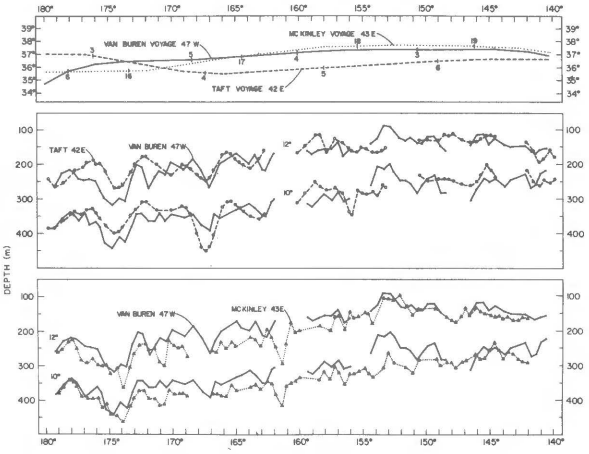
Scripps Institution, one of the major universities participating in the program, also serves as the center for administration of the project, which includes 34 scientists from 14 universities. Within the Scripps effort, two major areas of activity are being pursued: (1) statistical/analytical studies of the ocean and the atmosphere and their interactions, and (2) the monitoring of the thermal structure of the upper layer of the Pacific Ocean.

Analysis of statistical relationships has shown a close, local coupling between sea-surface temperature (SST) and atmospheric flow patterns in the sense previously hypothesized (*S10 Annual Report 1974,* p. 34). Experimental seasonal forecasts of temperature and precipitation patterns in the United States by Dr. Jerome Namias, based largely upon North Pacific



This experimental prediction for the spring of 1975 is shown side-by-side with temperature and precipitation patterns observed during the season. See NORPAX text for complete explanation.

Dr. Jerome Namias



The TRANSPAC program to monitor fluctuations in the thermal structure of the mid-latitude North Pacific was initiated during the year by utilizing observers aboard commercial ships that cross the Pacific regularly. See NORPAX text for explanation.

Dr. Robert L. Bernstein and Dr. Warren B. White

air-sea interactions, continue to be definitely superior to climatological expectancy. An experimental prediction (see illustration) for spring 1975 is shown side-by-side with the temperature and precipitation patterns observed during the season. In these illustrations the forecast and observed fields are expressed in three classes of equal climatological probability. The temperature classes are Above normal (A), Normal (N), and Below normal (B). Precipitation classes are Heavier than normal (H), Moderate (M), and Lighter than normal (LT).

Contingency tables for verifications of these forecasts, based on values at 99 3°x3° gridpoints in the Conterminous United States are shown below.

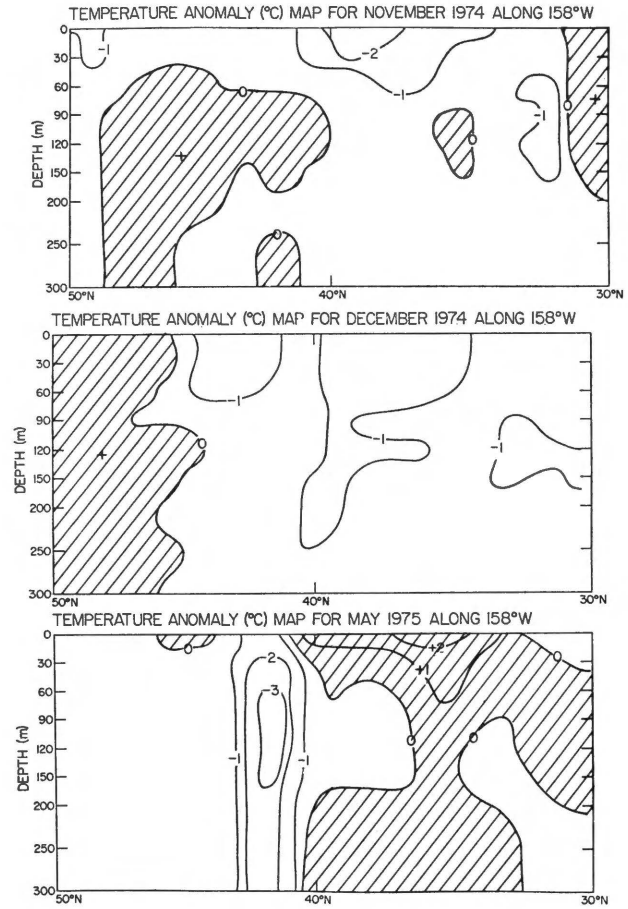
		Predicted Temperature Class		
		B	N	A
Obs. Temp. Class	B	47	20	0
	N	5	21	3
	A	0	1	2

		Predicted Precipitation Class		
		LT	M	H
Obs. Precip. Class	LT	1	1	11
	M	4	11	23
	H	1	19	28

As an explanatory example, note that of the 52 gridpoints that were predicted to have below normal temperatures, 47 actually were below normal, five were normal and none was above normal. Of the 99 gridpoints, 70 were predicted correctly compared to a statistical expectation of 33 correct.

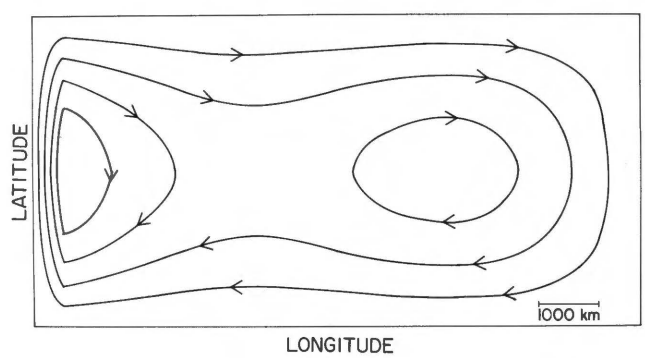
Studies by Dr. Hassan El-Sayed and separately by Charles K. Stidd have indicated that the use of eastern North Pacific atmospheric and SST data may lead to improved seasonal estimates of rainfall in certain California basins. Continental drought over parts of the United States, Russia, and the Sahel (the southern margin of the Sahara Desert), have been related to air-sea interactions over the North Pacific and North Atlantic.

A particular SST anomaly pattern in the eastern North Pacific which is likely to recur from one cold season to the next has been identified by Dr. Robert Dickson, of the Ministry of Agriculture, Fisheries, and Food, Lowestoft, England. The associated atmospheric flow pattern exhibits a similar recurrence tendency. Analysis of bathythermograph data indicates that, while the pattern does not retain its identity at the surface during the intervening warm season, the central core of the anomaly extends at least



Monitoring of near-surface thermal structure in central North Pacific between latitudes 30°N and 50°N complemented TRANSPAC program using aircraft and AXBTs in north-south sections across east-west ship tracks. Above three-part illustration is explained in NORPAX text.

Dr. Tim P. Barnett



This diagram explained in NORPAX text shows a model ocean circulation by means of the streamlines of horizontal flow.

Dr. Kern E. Kenyon

160 m below the surface, and persists as a major conservative element. The subsurface heat anomaly may then be resurrected by the deep stirring of the surface by fall and winter storms.

Further studies of the El Niño phenomenon by Dr. Namias and Dr. Tim P. Barnett have shown that the warm equatorial SST during El Niño are reflected in increased westerlies in the temperate North Pacific and a deepening of the Aleutian low. El Niño is also associated with an appreciably weakened Pacific high in the eastern Pacific, with reduced south trade

Two midshipmen from U.S. Merchant Marine Academy – Guy Klees, second from left, and Brian Peter, second from right – participated in NORPAX aboard R/V Alexander Agassiz, *dropping expendable bathythermographs off coast of Mexico at ocean temperature fronts identified earlier by satellite weather photos. Their work with Scripps amplified the usual chores the young men experienced during six months' training aboard ocean-going freighters. Presenting each with a Certificate of Appreciation on behalf of the institution are James A. Wells, marine technician, at left, and Capt. Peter S. Branson, manager of marine operations, at right. R/V* Oconostota *provides backdrop for photo, taken at Nimitz Marine Facility.*

Robert P. Huffer, at left, NORPAX operations manager, presents Certificate of Appreciation on behalf of the institution to Capt. James J. Colivas, master of SS President Van Buren, *for participation by American President Lines in TRANSPAC research (see NORPAX section).*
Photo courtesy American President Lines

winds during the preceding four seasons. These facts also appear to be reflected in a 50-year record of SST at Puerto Chicama, Peru, whose statistics lead to a probablistic method for forecasting El Niño, or its inverse, a season or more in advance.

Dr. Kern E. Kenyon has been studying the mean sea-surface temperature in the North Pacific in an attempt to better understand the sea-surface temperature anomalies that have been associated by Dr. Namias with anomalous weather conditions. Climatological records show unexpectedly a basin-wide, small-amplitude (1°C), variation with longitude in the mean sea-surface temperatures, a simple, steady-state, wind-driven, ocean-circu-structure appears to be a permanent feature, and it is best expressed at mid-latitudes (30-40°N). Seasonal variations in both amplitude and position of the temperature wave are also apparent in the historical data. Non-seasonal changes in the wavy temperature structure are the manifestations of the sea-surface temperature anomalies.

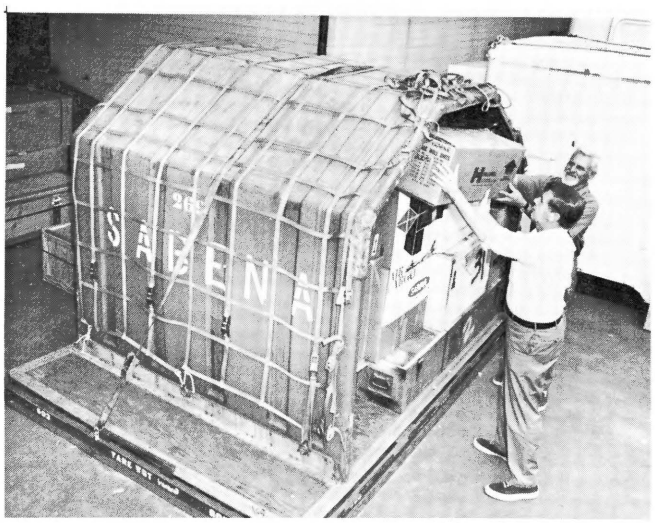
In order to try to understand the cause of unusual patterns in the mean sea surface temperatures, a simple, steady-state, wind-driven, ocean-circulation model has been constructed. The accompanying diagram shows the model ocean circulation by means of the streamlines of horizontal flow. In this model, the driving force of the wind varies with longitude in qualitative agreement with the wind pattern that would be produced by the observed variations with longitude of the mean sea-level pressure of the North Pacific. The similarity between the wavy character of the concentrated eastward flow along the northern boundary of the model and the wavy character of the observed mean sea-surface temperature suggests (but does not prove) that the wind structure may cause the temperature structure. Although the model is extremely simplified, it contains several additional interesting features, such as the concentration of southward flow along the eastern boundary, the clockwise recirculation in the eastern half of the basin and the recirculation outside the western boundary current. Studies of the existing data and simplified mathematical ocean models are continuing in an attempt to shed further light on the problem, and a cruise is being planned to obtain needed subsurface temperature and salinity data in the North Pacific.

Two coordinated efforts in monitoring the fluctuations in the thermal structure of the mid-latitude North Pacific Ocean have been initiated during the last year. The first is the TRANSPAC program of Drs. Warren B. White and Robert L. Bernstein, in which observers are placed aboard commercial ships (see illustration) that cross the Pacific Ocean regularly. By utilizing these platforms-of-opportunity, the area from 30-40°N, 140°W to 150°E has been continuously monitored for the first time, with significant results. The accompanying three-part figure, taken from data collected by TRANSPAC ships-of-opportunity, provides an illustration of the rapid time variability of the main thermocline observed over this large area. In the upper portion of the figure are three, nearly parallel ship tracks; one pair of tracks (*Taft* 42E and *Van Buren* 47W) is separated by less than two days in time, but the tracks have an approximately 150-km north-south separation. The other pair (*Van Buren* 47W and *McKinley* 43E) are separated by less than 20 km, but they have a 12-day time separation. In the middle section of the figure, the 10-and-12°C isotherm depths have been selected as representative of the main thermocline, and the illustration shows that the synoptic pair agree quite well despite the 150-km space separation. On the other hand, the time-lag pair shown in the lower portion of the figure reveals that an approximate 50-m descent of the isotherms occurred during the 12-day period. As a major winter storm was tracked slightly north of these observations, it is reasonable to suspect that this was responsible for the changes in thermocline structure. Based on these and other data, the Anomaly Dynamic Study (ADS) has been initiated to study the cause of these changes.

Dr. Barnett has monitored the near-surface thermal structure in the central Pacific Ocean between latitudes 30°N and 50°N in a program that complements the TRANSPAC program by taking north-south sections across the east-west ship tracks. These observations have been taken monthly by using U.S. Navy P-3 aircraft and airborne expendable bathythermographs (AXBTs) furnished by the Pacific Fleet. The field operation involves leaving Adak in the Aleutian Chain and flying down 158°W, dropping AXBTs every 80 km between 50°N and 30°N. After a two-day layover in Hawaii, the plane returns to Adak along the 170th meridian,

again dropping AXBTs between 20°N and 50°N. Preliminary inspection of these data indicates that sea-surface temperature anomalies have several types of vertical structure. One type of anomaly is confined to the region above the mixed layer, generally to a depth of less than 90 m (see upper portion of accompanying figure). This type of anomaly is probably caused by excessive air/sea heat exchange. Another type of anomaly is seen (middle section of figure) to extend from the surface down to the maximum depth of observation (300 m and beyond). This may be caused by penetration convection. A final type of anomaly seems to be "oceanic" in origin (lower section of figure), with a maximum intensity at depth (*e.g.*, 150 m) and being narrow in north-south extent (*e.g.*, 300 km) as opposed to the typical 1,000-to-1,300-km, north-south dimension of sea-surface temperature anomalies. A southward shift of the Subarctic front could have caused this feature.

These descriptions of the spatial, vertical structure of the ocean temperature anomalies are the first of their kind. Further documentation of these types of anomalies should allow us to describe the different physical mechanisms responsible for their creation.



Igloo-like airline container is filled with two tons of equipment and supplies by Dr. Harmon Craig, professor of geochemistry and oceanography, foreground, and Fred S. Dixon, development technician. Cargo was shipped to Bujumbura, Burundi, in east central Africa, where Dr. Craig, Dixon, and Dr. Ray Weiss, research geochemist, collected water samples and sediment cores from nearby Lake Tanganyika. Samples were sent to Scripps for radioisotope and chemical analyses to study chemical and particulate processes, vertical mixing of the water, and history of the nearly 1,400-m deep lake. Project was collaborative effort funded by the United Nations Development Program, Food and Agricultural Organization, Rome, and the Burundi government, and is a continuation of previous expedition work done in 1973.

Ocean Research Division

Within the Ocean Research Division of Scripps Institution, a multitude of varied research projects is carried on in biological oceanography, marine chemistry and geochemistry, geophysics, and physical oceanography.

Dr. Walter F. Heiligenberg has been studying the convergent evolution in mechanisms of electrolocation in fish. Weakly electric fish generate electric fields by continually firing their electric organ. Electroreceptors in the animal's skin monitor local intensities of the electric field emanating from its body. Objects differing electrically from the surrounding medium distort electric fields and can, therefore, be detected on the basis of local changes in electroreceptive feedback. The South American *Gymnotoidei* and the African *Mormyriformes* evolved electric organs and electroreceptors independently of each other. The present study also reveals convergent evolution on a behavioral level.

Whereas some species of electric fish fire their electric organ in a sinusoidal manner and at highly stable frequencies ("wave-type" discharges), others fire their electric organ in short pulses and at irregular frequencies, with short rises in frequency being most common in novel situations ("pulse-type" discharges). Both types of electric fish are found among the African and South American species. The fact that both types may occur even within the same family suggests that this evolutionary dichotomy has occurred several times in electric-fish history, and that either mode of discharging represents an evolutionary adaptation to particular environmental conditions.

Electrolocation is similar to echo location in that the animal assesses its environment by analyzing feedback from signals that it actively generates. In both cases, feedback has to be purged from interfering signals emitted by other individuals. Previous studies revealed that the South American wave-species, *Eigenmannia,* requires a private frequency band around its own discharge frequency to electrolocate objects with sufficient accuracy. *Eigenmannia* maintains its private frequency band by shifting its frequency of discharging away from frequencies of near conspecifics. The same strategy of "jamming avoidance" was demonstrated in the nonrelated African wave-species, *Gymnarchus*. In the same manner as shown in *Eigenmannia, Gymnarchus* fails to detect objects if sinusoidal electric stimuli of sufficient intensity, mimicking discharges of a conspecific, approach its own discharge frequency (see accompanying illustration). Nonrelated wave-species thus appear to have invented the same behavioral strategy to separate electroreceptive feedback from interfering noise. Preliminary studies indicate that pulse-species employ a different strategy of jamming avoidance, and that in another example of convergent evolution, African and South American species have evolved the same mechanisms.

Dr. D. John Faulkner concentrated his research activities on the chemical constituents of organisms low on the evolutionary scale in the marine environment. He paid particular attention to compounds that show antimicrobial activities and/or play significant roles in marine ecosystems; *i.e.*, chemical communication, defense mechanisms, and chemical ecology. In many cases, he undertook the synthesis of these active components and other biologically important natural products.

At present, antibiotic metabolites from several species of porifera, mollusca, and benthic algae are being isolated and identified. The integral role red algae play in the life cycle of molluscs is also of great interest.

Dr. Charles D. Keeling's group continued to investigate the geochemistry of carbon dioxide, with the most recent emphasis placed on obtaining a reliable prediction of future increases in atmospheric CO_2 resulting from burning fossil fuels (coal, petroleum, and natural gas). This prediction will be incorporated in a report on world energy being prepared by the U.S. National Academy of Sciences. Since the rate of fossil-fuel burning from year to year cannot be accurately known in advance, the prediction focuses (1) on establishing the fraction of fuel-derived CO_2 that remains airborne and (2) on long-range trends. Calculations projected through the entire fossil-fuel era and beyond, to A.D. 3500, indicate that large increases in CO_2 are to be expected — up to eight times present levels — and that after most of the world's fossil fuel is burned, the concentration will fall only slowly and remain at more than twice the present level for at least 1,000 years.

These studies have been supported by experimental data collected by Dr. Keeling and his collaborators during the past 17 years at atmospheric base-line stations in Hawaii and at the South Pole, with supplemental stations in New Zealand, on Fanning and Christmas islands near the equator, and on Canadian Weather Ship *"P"* at 50°N. To assure the accuracy of the historic record based on these data, the CO_2 group has completed a four-year recalibration of standard gases used in the field programs and has established, as of 1974, a provisional calibration scale for the nondispersive, infrared, gas analyzers used in the program.

During March 1975, Keeling's group was host to an international panel of experts on atmospheric CO_2. The panel was convened by the World Meteorological Organization (WMO) to further international cooperation in measuring atmospheric CO_2 at an expanded network of base-line stations under consideration by WMO. As a result of a recommendation from the meeting, the Scripps Institution has been named by WMO as a Central CO_2 Laboratory, with the Scripps 1974 CO_2 calibrating scale provisionally to be used as a common basis for reporting all CO_2 data gathered in the WMO-sponsored base-line program.

In further work, Dr. Robert B. Bacastow continued a study of periodicities in atmospheric CO_2 concentration related to the southern oscillation in barometric pressure, and Peter R. Guenther began a redetermination of the dissociation constants of carbonic acid in seawater based on measuring the partial pressure and total amount of CO_2 in waters of varying salinity and temperature.

Dr. Tsaihwa J. Chow's group continued studying the marine chemistry

Staff research associate David Muus (left, top photo) prepares to launch an STD recording instrument from USCGC Glacier *an ice-covered antarctic waters during International Weddell Sea Expedition. The STD recorder is used to measure salinity and temperature as a function of depth. In middle photo, Sir George Deacon, Scripps research associate and for many years director of the National Institute of Oceanography, Wormley, England, operates STD aboard* Glacier. *At bottom Muus takes a sea-ice core in seven-to-ten-m-thick ice in Erebus and Terror gulfs, in western Weddell Sea, where* Glacier *was beset for ten days in heavy ice floes. Core is to be analyzed by Dr. Robert Michel, of the UCSD Department of Chemistry, for tritium content in order to estimate age of ice.*

Dr. Theodore D. Foster

of lead, completing such research projects as (1) the distribution of lead in marine organisms and (2) the variation of lead-isotope ratios in the Deep Sea Drilling Project sediment cores.

Project (1): Adverse effects of toxic substances on the environmental quality have become a concern in recent years. It is well known that the discharge of lead compounds into coastal waters through man's activity surpasses that from river runoffs.

Since trace-metal concentrations of seawater are one of the factors that influence those concentrations in marine organisms, the accumulation of lead in marine organisms that can be used as an environmental quality indicator has been determined. *Mytilus* sp. was chosen as the representative organism because of its worldwide distribution and availability in the intertidal zone. Specimens were collected along the Pacific coast from Piedras Blancas Point, near San Simeon, California, to Punta Bunda, near Ensenada, Baja California. This coastal zone depicts varying degrees of industrialization ranging from relatively undisturbed to heavily developed regions.

A definite correlation between the lead content of *Mytilus* and man's activity along the coastal zone was observed. For regions in California such as Piedras Blancas, Cayucos, and Gaviota, which are sparsely populated, the lead content of the whole tissue of *M. californianus* (sea mussel) was lowest. Lead contents of those collected at Goleta and Rincon Point increased slightly. High lead contents were obtained in *M. californianus* collected southward along the more densely populated coast. The highest average lead for *M. californianus* was found in La Jolla specimens; they showed a value about 15-fold higher than that of the Cayucos samples.

Mytilus edulis (common mussel) is usually found in quiet waters; therefore, specimens of *M. edulis* were collected from docks in marinas or bays where the effects of man's increased activity is definitely evident: they showed a concentration about 100 times that of the lowest concentration found.

The lead concentrations of various organs (gill, stomach, gonad, and muscle) in *Mytilus* sp. were determined. Organs from harbor mussels contained higher lead content than corresponding parts in mussels from relatively undisturbed regions. At each location the gill tissue contained the highest amount of lead. This finding might be expected since seawater is continuously circulated past the gills, and the removal of heavy metals from seawater by the gills through chelation would promote pollutant concentrations in this region.

Project (2): The study of the geochronological variation of lead isotopes in Deep Sea Drilling Project (DSDP) sediment cores will provide data to construct a lead isotopic-regression curve that can be used to interpret continental crust differentiation. Dr. Chow and his colleagues have studied 18 DSDP cores of various-depth segments from the North and South Atlantic. The oldest sediment examined was from the Jurassic. The lead contents of sediment varied from 0.32 to 84 ppm. The isotopic ratios of lead in those DSDP sediments are now being interpreted.

Dr. Chow was one of the U.S. delegates to the United Nations Conference on Isotope Ratios as Pollutant Source and Behavior Indicators, jointly sponsored by the U.N. Food and Agriculture Organization and the International Atomic Energy Agency in Vienna, in November 1974.

Dr. Joris M. T. M. Gieskes, utilizing sediment cores from the Deep Sea Drilling Project, continued investigations on the chemistry of interstitial waters of marine sediments. In particular, the results of Leg 35 of DSDP in the southeast Pacific Ocean, on which an intensive collaborative effort by chemists and mineralogists was launched, have led to a more detailed understanding of the diagenetic processes in sediments and underlying basalts that are the cause of observed concentration gradients in the interstitial waters.

Russell E. McDuff, a graduate student, has almost finished developing models for the evaluation of diffusion profiles in sediments. These models account for variable sedimentation rates and variable diffusion coeffi-

cients. The latter can and will be evaluated by using conductivity techniques. John T. Turk, graduate student, continued work on the subject of the usefulness of this conductivity technique with respect to diffusion problems in clay-water systems. Gerald S. Wirth, a graduate student, pursued research on the solution chemistry of silica in aqueous salt solutions, using sound-absorption techniques for the evaluation of the kinetics of ionization of silicic acid.

Drs. Theodore R. Folsom and Vernon F. Hodge continued their studies of the behavior of extremely small traces of artificial and natural radioactivity in the ocean, using facilities developed for this purpose at the Mt. Soledad Laboratory. By using low-level alpha-particle spectrometers, they demonstrated (1) that natural polonium and artificial plutonium nuclides collected on algal and many other surfaces in the ocean at rates predictable from the hydrodynamic theory of aqueous boundary films, provided it is assumed that these heavy elements diffuse in seawater at velocities characteristic of large, spherical macromolecules with diameters near 1/100 microns; (2) that these heavy-metal curies are absorbed superficially in many surfaces; and (3) that the weaknesses of the diffusion-limiting, aqueous, boundary layers on algal surfaces derived in the alpha-particle studies are consistent with boundary-layer weaknesses, implied by reported studies of respiration and nutrition of algae such as kelp.

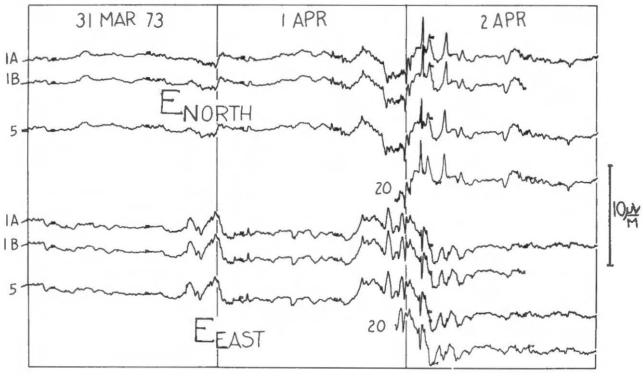
The Shore Processes Study Group, under Drs. Douglas L. Inman and Clinton D. Winant, was engaged in studying the physics of the nearshore environment. This group is composed of approximately ten graduate students and a professional and technical staff of more than 20, who occupy space in the Shore Processes Laboratory and the Hydraulics Laboratory.

Research objectives of the group included (1) field and laboratory measurements of wind, waves, currents, and sediment transports; (2) identification and study of the important physical processes operative in the nearshore environment; (3) application of the understanding of these processes to environmental problems of the coastal zone; and (4) formulation of criteria for coastal-zone planning.

The basic research objective of making meaningful field measurements in the nearshore environment was attained with the use of versatile instrumentation that was developed by Robert L. Lowe, electronics engineer for the group. The Shelf and Shore (SAS) simultaneous data-acquisition system consists of several shelf stations deployed offshore for measuring data, and a shore station for receiving and recording data. Each shelf station is a buoyant spar coupled to an anchor on the bottom by a universal joint. A variety of sensors can be attached to each shelf station for making measurements of waves, currents, and temperature, which are telemetered back to the shore station. The shore station can receive data from several shelf stations simultaneously and record them for later processing. Data processing is done with a minicomputer housed in the Shore Processes Laboratory. A direct communication link between the shore station and the minicomputer permits a real-time analysis of data.

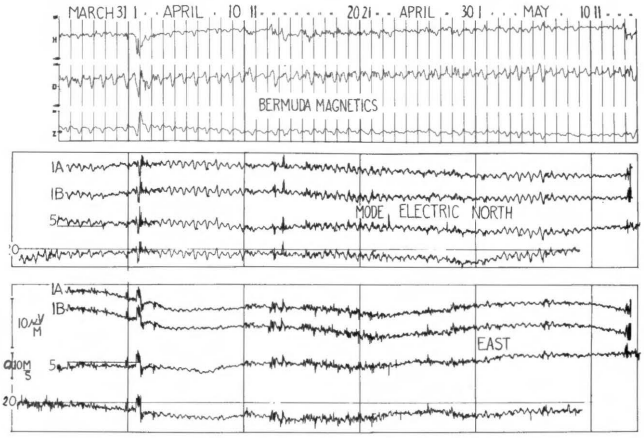
Shelf stations have been installed off Torrey Pines Beach (three km north of Scripps), in the head of Scripps Canyon, on the shelf between Scripps Canyon and Scripps Pier, and off the end of Scripps Pier. The Torrey Pines Beach station is used to measure the local wave climate from a line array of pressure sensors on the bottom. More than three years of wave-climate data have been recorded from this site. The first year-and-a-half of the data have been thoroughly analyzed and are being published as a *U.S. Army Corps of Engineers Coastal Engineering Research Center, Technical Memorandum*. The shelf station in Scripps Canyon is designed to measure surface waves and currents in the submarine canyon. Current measurements made with this installation and previous instruments enabled the mechanism for the generation of strong currents in submarine canyons to be determined and verified. A technical paper by Dr. Inman, Charles E. Nordstrom and graduate student Reinhard E. Flick has been prepared that describes the generation mechanism for strong canyon currents and the definitive canyon current data. The third and fourth shelf stations located near Scripps Pier are equipped with pressure sensors to measure surface waves. Data from these two stations measured synoptically with those from the other stations are being utilized in a study of edge waves trapped on the shelf.

Dr. Winant has been investigating the presence and nature of breaking internal waves and bores in the nearshore environment for the past two years, using an array of thermistor chains and pressure sensors in the vicinity of Scripps Pier. Breaking internal tides cause large temperature changes to occur in shallow water, sometimes quite rapidly. Bottom temperature changes on the order of 5°C occurring in a few seconds have been measured at the end of Scripps Pier. These temperature changes are accompanied by currents of the order of 10 cm/sec that last for several hours. The internal-wave studies on the shelf have been expanded to include thermal and current measurements at the Naval Undersea Center oceanographic tower off Mission Beach, in San Diego (in conjunction with Jack R. Olson of NUC). These measurements indicate the summer currents in



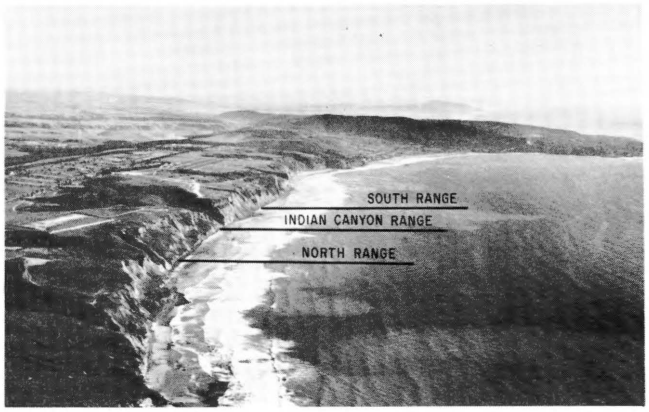
Horizontal electric fields are shown above at Stations 1A, 1B, 5, and 20 during a magnetic storm, March 31-April 2, 1973. Note high coherence not only between adjacent stations 1A and 1B, but also between the other two stations, 5 and 20, each at a distance of 100 km from Station 1A and 1B. Plot shows both horizontal components on same scale (indicated to right). Station numbers are indicated by numerals at left end of each trace.

Dr. C. S. Cox and Dr. Jean H. Filloux



Data charted above are from Bermuda magnetic observations and horizontal electric fields taken from March-April, 1973, at Stations 1A, 1B, 5, and 20. Electric north components are plotted in group above electric east components. Rapid fluctuation with periods up to one cycle per day are caused by coupling with ionospheric disturbances. Very low frequency fluctuation of electric field (periodicity greater than one week) appears to be caused by conduction from slow changes of ocean circulation.

Dr. C. S. Cox and Dr. Jean H. Filloux



Aerial photograph of Torrey Pines Beach, near Scripps Institution, showing location of three range lines used by Shore Processes Study Group to measure changes in equilibrium beach profile during past three years.

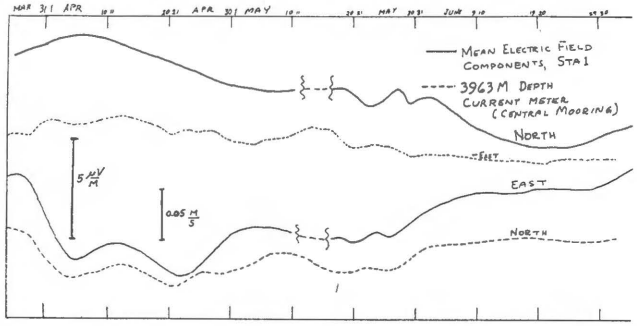


Chart compares horizontal electric field components at Station 1A with water-current record obtained at depth of 3,965 m at MODE central mooring (about 3 km from 1A). Comparison is based on $\underline{E} = -u \times \underline{B}$. *The electric records have been smoothed by eye to remove frequencies above 0.2 cpd. This takes out all ionospheric-induced signals. It is satisfactory that the electric records show larger amplitude signals, because the 3,965-m current had lowest intensity of all the records (391, 489, 691, 1,392, 2,916, and 5,356 m).*

Dr. C. S. Cox and Dr. Jean H. Filloux

Dr. Douglas L. Inman, at right, explains a 100:1 slip model of system conceived for removing silt from slips at Mare Island Naval Shipyard. Unconsolidated silt is entrained by water jets and transported out of slip into deep water. In this configuration, multiple jets remove diatomaceous earth used as an artificial silt.

Shore Processes Study Group

the area to be driven alongshore by surface tides and the longshore component of wind; in contrast, onshore currents are primarily caused by internal tides. Laboratory studies of internal bores are also being carried out in the Hydraulics Laboratory's glass-walled wave channel to further define the characteristics of these wave forms.

The mechanics of the equilibrium beach profile is being studied by Dr. Inman and a graduate student, David G. Aubrey, at Torrey Pines Beach. This study in part involves making detailed measurements of beach profiles along a 2.6 km segment of beach and comparing the beach response to the incident-wave energy. This complements a prior study of seasonal sand-level changes on this same beach completed by Nordstrom and Dr. Inman, and is being published. Drs. Winant and Inman and Nordstrom also applied an empirical eigenfunction analysis to describe these beach-profile data. The ultimate aim of these beach studies is to obtain a capability of predicting the beach-profile configuration as a function of the varying incident-wave energy.

Dr. Inman and Flick are conducting laboratory investigations that will seek to define the conditions for resonant long-wave generation in the surf zone. The first part of the study will seek to define the input conditions for

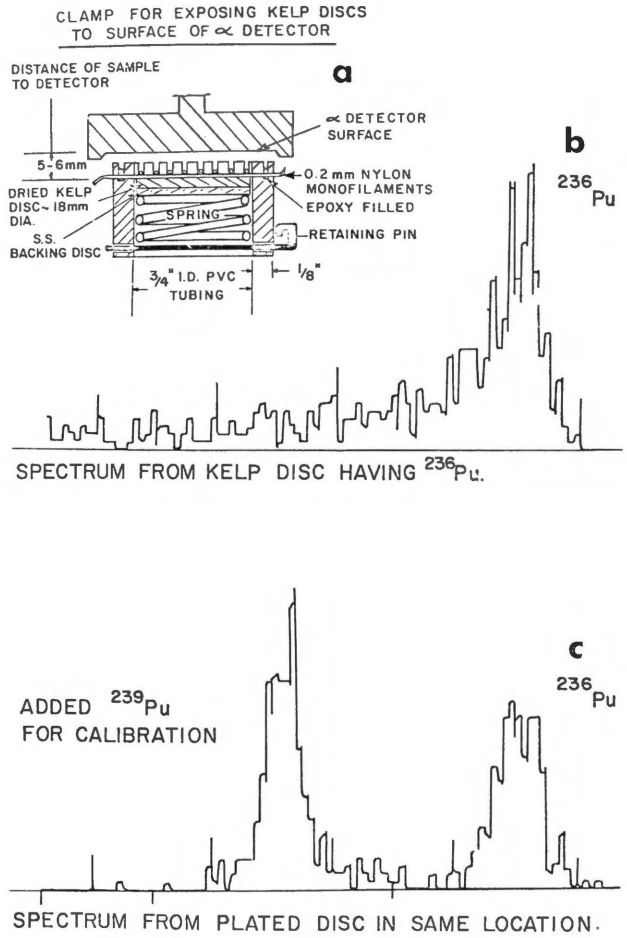
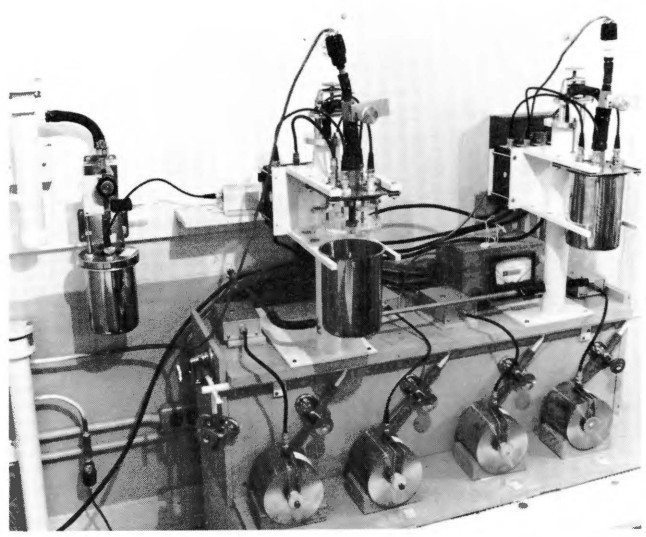


Diagram of demonstration of superficial nature of plutonium contamination on kelp blades in deliberately contaminated seawater baths. Dried blade, held before an alpha detector, produced an energy spectrum whose peak and degenerate tail accounted for large fraction of ^{236}Pu *deposited on blade. Penetration of deep mass for about 50 microns would have caused complete tissue absorption and an empty spectrum.*



Photograph shows vacuum chambers and amplifiers associated with 13 spectrometers used for counting extremely small traces of alpha emitters at Mt. Soledad Laboratory for Marine Radioactive Studies. A most recent improvement is the mounting together of four detectors (right foreground) in each of two vacuum chambers (upper right), one of which is in the open position, the other closed.

shoaling-wave experiments in a wave tank to account for the effects of paddle-wave generation, of reflection, and of the natural oscillations of the wave tank. The second part of the study will seek to determine the wave conditions necessary to generate long waves and anomalously high run-up in the surf zone. These laboratory results will then be used to design a field experiment to determine whether long, two-dimensional waves are generated in the real surf zone, and to separate the effect of these waves from that of the three-dimensional, edge waves at the same frequencies already known to exist.

Drs. Inman and William G. Van Dorn and Rolland Harris, dredging consultant, have been investigating an improved technology for artificially moving sand and silt. These investigations involve the study of fluidization and directed jet flow to move sediment from areas where siltation is a problem. Work on this study is continuing in the granular-fluids basin and specially designed basins in the Hydraulics Laboratory. Results from this study to date have shown that laterally directed jets placed near the bottom are an effective and efficient method for moving fine-grained sediment from areas of pronounced siltation, such as those around piers and wharfs. The sand-fluidizing studies have successfully progressed through theoretical, laboratory, and field tests. Both the fluidizing and laterally directed jet techniques are ready for full-scale, prototype, field testing.

During the first half of this reporting period, Dr. Van Dorn completed and reported on a four-year laboratory investigation of wave-breaking in deep and shallow water. During the second half, Dr. Van Dorn joined with Dr. Inman to commence a study of alternatives to dredging for sediment control within harbor facilities.

Several projects related to the ecology of kelp communities were continued by Dr. Paul K. Dayton and his group. Long-term base-line studies of natural population fluxes were continued in California kelp beds off Catalina Island, Del Mar, and Point Loma. An intensive program is underway at Point Loma that includes a long-term study quantitating the mortality patterns resulting from drift kelp plants, studies of hierarchies of dominance in the competition for light among several species of algae, studies of the community ramifications of the activities of various herbivores and carnivores, and studies of growth rates of several species of algae. Student projects in the kelp community include those of Brock B. Bernstein on the population dynamics of several species of bryozoan and their predators, all of which inhabit kelp fronds, and Jeffrey D. Rude's study of the sponge association that occurs under ledges in kelp beds. Dr. Mia J. Tegner directed a large program on the population dynamics and resource management of local sea urchins.

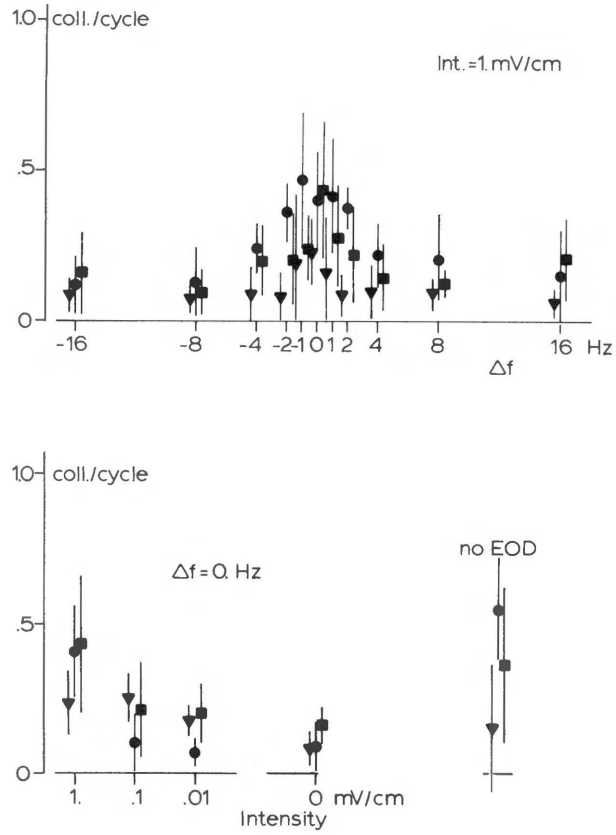
A long-term (begun in 1967) Antarctic research program studying community interactions in the nearshore benthos in the McMurdo Sound vicinity was continued. The current thrust of the sponge community research is directed toward the reproductive and defense strategies of sponges (a component of Rude's PhD project). This is a continued and refined analysis of spatial distribution patterns as influenced by depth, sedimentation, competition for primary space, and predation. New studies included the ecology of the association of animals that fouls hard substrata, larval ecology, and settling behavior. An intensive study of succession in the soft-bottom community forms the basis of the thesis of John S. Oliver.

Research of other students working under Dr. Dayton's direction included predator-prey interactions in the sand-bottom community (Noël D. Davis and Glenn R. Van Blaricom), population dynamics of a Caprellid amphipod (George S. Lewbel) and several species of local cup corals (Timothy Gerrodette), microdistribution and population dynamics of the fauna associated with large intertidal algae (Frederic C. Gunnill), and the ecological implications of the local invasion of *Sargassum muticum,* a Japanese seaweed (Lawrence E. Deysher).

Dr. Jeffrey L. Bada continued work on the use of the amino-acid-racemization reaction in dating fossil bones and shells, deep-sea sediments, and other fossil materials. One area of emphasis has been the dating of numerous human skeletons from North America. The results of these analyses have provided further documentation that man was present in North America at least 50,000 years ago. Dr. Bada has identified five sites in southern California and a possible site south of San Francisco that have yielded paleo-indian skeletons 40,000 to 60,000 years old.

Aspartic-acid-racemization reaction has also been used by Dr. Bada to estimate the ages of fossil bones from sites in South Africa, Kenya, Tanzania, Israel, Egypt, France, and Spain.

Another important area of investigation has been the prediction that aspartic-acid racemization might also take place in structural proteins that are not regenerated during the life-span of long-lived mammals. To test this prediction, Dr. Bada analyzed enamel from teeth extracted from human beings of various ages. The results indicate that aspartic acid in enamel shows increasing racemization with age. Thus, racemization may play some role in the aging process affecting metabolically stable tissues in long-lived homeotherms. Aspartic-acid racemization in tooth enamel also provides a biochronological tool for assessing the age of living mammals.



Upper diagram of figure shows that rate of collisions with standardized object (ordinate) increases if the difference, Δf (abscissa), between animal's discharge frequency and frequency of a sinusoidal electric stimulus of at least 1 mV/cm intensity approaches zero. Lower diagram indicates that, for a Δf of zero, rate of collisions (ordinate) increases with increasing intensity of stimulus (abscissa). As to be expected, collisions are frequent during periods of interrupted electric organ activity (far right: no EOD). Means and standard deviations of three specimens, slightly displaced along their abscissa, are presented. Constant Δfs were maintained by "clamping" stimulus frequency to animal's discharge frequency.

Dr. Walter F. Heiligenberg

During 1974-75, Dr. Robert S. Arthur and Joseph L. Reid completed a manuscript, "Interpretation of Maps of Geopotential Anomaly of the Deep Pacific Ocean," which appeared in *Journal of Marine Research,* supplement to Vol. 33, 1975. Dr. Arthur continued the development of a syllabus for lectures to nonphysical oceanographers on the principles and applications of dynamical oceanography.

Dr. Russ E. Davis examined nonseasonal variability of sea-surface temperature in the central North Pacific and its relation to anomalous changes in the sea-level pressure of the overlying atmosphere. Statistical predictors were developed in order to examine the degree to which these two fields are connected and whether one causes the changes in the other. It was learned, as expected, that sea-surface temperature anomalies can be predicted for a few months. A connection between sea temperature and atmospheric pressure was established; anomalous pressure can be specified by sea temperature data from the same month. The fact that prior atmospheric states can be specified from sea temperature, but future states cannot be predicted using the model developed, suggests that the cause of the connection is the atmosphere driving the ocean.

Dr. Davis and graduate student Lloyd A. Regier have recently completed an observational program describing the directional frequency spectrum of surface waves. A new method of estimating directional spectra from arrays of wave sensors was developed and used to relate the structure of the sea state to winds. Significant departures from the theoretically predicted frequency to a minus fifth-power spectrum were found along with a tendency for low-frequency waves to be more concentrated around the direction of the prevailing wind than were high-frequency waves. Attempts to characterize the spectrum in terms of local winds show that the

sea state is, to a degree, larger than anticipated, dependent on other variables such as fetch and duration of the wind.

Dr. Robert A. Knox continued his investigation of equatorial currents in the Indian Ocean and the strong seasonal variations thereof that are driven by the seasonal winds (monsoons). A program of weekly current and temperature profiles to 300 m near the equator in the central part of the ocean is ending, because of the closing of the Royal Air Force base at Gan, Maldives, from which the observations were carried out. Final analysis of this long record (more than two years) is in progress. A new project to set and maintain moored current meters at the equator north of the Seychelles for from one to two years has just begun. These measurements will document long-period fluctuations in the deeper water, at about 500 m. This project, together with similar exploratory measurements by investigators from a number of institutions and countries, will gather data needed to design a large and definitive field experiment to measure the response of the Indian Ocean to wind forcing. This larger experiment is now planned for 1978-79, at which time, by virtue of the meteorological First GARP Global Experiment (FGGE), the winds over the ocean will be much more intensively sampled than by routine land stations and ship reports.

Drs. Charles S. Cox and Jean H. Filloux participated for four months in MODE (Mid-Ocean Dynamic Experiment), a comprehensive attempt to describe the water motions in the deep sea throughout a 400-km square of the Sargasso Sea. As part of this experiment, electric field recorders were placed on the sea bottom at three stations at the corners of a right triangle, 100 km on a leg. Barotropic water motions in the ocean produce electric fields in the water. The electric recorders respond to these ocean fields that are superimposed in turn on fields induced by ionospheric disturbances and magnetic storms. Three accompanying figures illustrate the character of the recorded fields and a comparison of the electric field with a current-meter recording.

Drs. Filloux and Cox are further exploring the method for registering barotropic motions by maintaining an instrument at a point 124 km southwest of San Diego under the California Current. The purpose is to examine the mean flow of this oceanic eastern boundary and to study its fluctuations.

The signals induced from inospheric sources are of great value, when correlated with magnetic measurements, for studying the constitution of the upper mantle beneath the ocean. Following the successful recording of signals in the MODE experiment, these investigators are proceeding toward systematic exploration of the method. To this effect, sizable arrays of electric and magnetic field recorders are being prepared to allow broad, special coverage and sustained recording duration at a modest expense. First deployment should occur in mid-1976 in the north central Pacific Ocean.

Dr. R. Edward Lange, working with an instrument designed by Dr. Cox, developed a velocity/temperature microstructure recorder. This instrument is a freely falling, autorotation device that uses large air foils to achieve slow, controlled, fall rates and rotational stability. It records eight high-speed data channels internally, and then drops ballast and returns to the surface to be picked up by ship.

The instrument is capable of "seeing" velocity fluctuations in both horizontal and vertical components smaller than 0.1 mm/sec, and can "see" background velocity fluctuations typical of the open ocean. To date, 30 drops have been made in the Pacific Ocean off San Diego. They show unexpectedly low levels of velocity activity (seldom exceeding 1 mm/sec), most frequently associated with the bottom of temperature inversions. One record under examination seems to show a 10-m vertical patch of turbulence, isotropic in velocity fluctuations, with scales below 30 cm. The motions of this instrument are fully documented by accelerometer- and rotation-measuring magnetometers, and represent the state-of-the-art in oceanic, fine-scale, velocity measurements.

Dr. Theodore D. Foster led the International Weddell Sea Oceanographic Expedition aboard the USCGC *Glacier* in an investigation of Antarctic Bottom Water formation in the northwest Weddell Sea. Sir George Deacon has studied this southern ocean for many years and collaborated in the physical oceanography program. Three current meters equipped with temperature and conductivity sensors were set out in the region where Antarctic Bottom Water flows out of the Weddell Sea. It is hoped to retrieve these current meters in 1976, and thereby obtain year-round records of the variability of Antarctic Bottom Water formation. The unusual small-scale temperature-and-salinity structure encountered in the central Weddell Sea was investigated with a fast-response, conductivity-temperature-depth profiler. Nearly isothermal and isohaline layers up to 55 m thick were measured.

Dr. Carl H. Gibson worked with some ideas that had been developed on the nature of turbulence in a stably stratified medium and the resulting effects on scalar fields, such as temperature and salinity mixed by the turbulence. Stratification may rapidly dump out turbulence at large scales by radiation of its energy as internal waves, leaving residual, partially mixed, scalar fields as a form of "fossil" of the turbulent event. Attempts have been made to devise methods of extracting information about previous "events" from such "fossils," so that models of the consequent vertical diffusion can be constructed and used in conjunction with oceanic temperature-and-salinity measurements to infer vertical fluxes.

Analysis of the data taken by towing high-frequency-response, temperature-and-velocity sensors in the surface layer off San Diego and near western Australia shows significant departures of temperature from "universal" spectral forms suggested by laboratory measurements in active, neutrally stratified, turbulent mixing. Attempts to interpret these and other oceanic microstructure measurements as "fossil turbulence" have been carried out with some success. Laboratory studies are planned to provide further information on the structure of mixing in stratified fluids.

Working with graduate students Richard L. Salmon and Gregory Holloway, Dr. Myrl C. Hendershott studied the theory on the influence of gentle but persistent perturbations of large-scale, turbulent-fluid, flow systems such as those that occur in the ocean and atmosphere. The predicated effects on the atmosphere of perturbation caused by mid-latitude sea-surface temperature anomalies appear to be in close correspondence with Dr. Davis' analysis of historical observations.

With graduate student Michael E. Parke, Dr. Hendershott developed a technique for including ocean self-attraction and solid-earth yielding in ocean-tide models. The results are to be applied to a study of ocean tides from satellite (GEOSECS) altimetry.

Physiological Research Laboratory

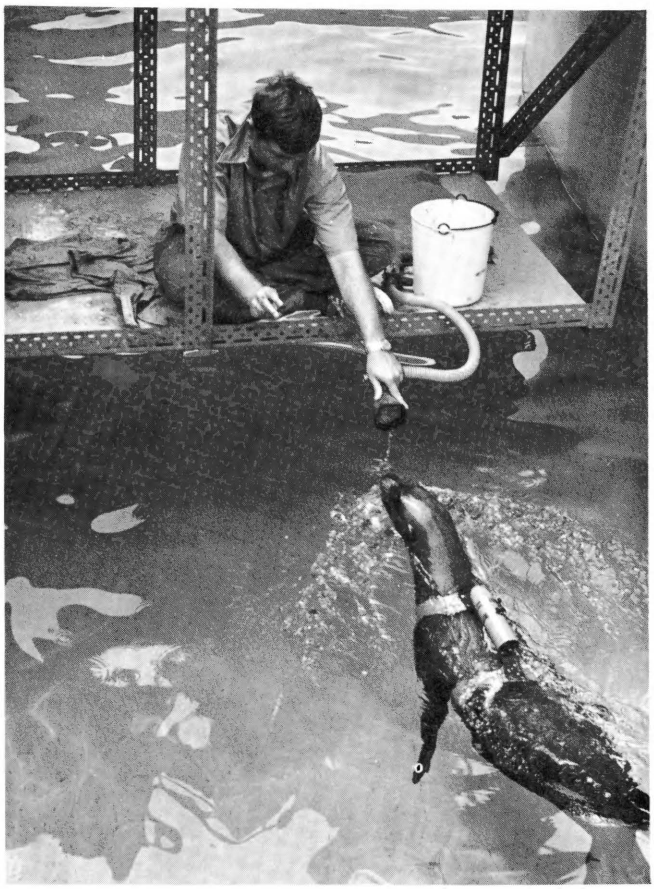
The blood of fishes that live in ice-laden seawater is fortified with substances which serve as biological "antifreeze" agents. These antifreezes lower the freezing point of the blood of these fishes below the freezing point of seawater (−1.9°C). A field party under the direction of Dr. Arthur L. DeVries returned to McMurdo Sound, Antarctica, in 1974 to study this unique adaptation in antarctic fishes.

McMurdo Sound is an ideal study site because its water is at its freezing point of −1.9°C throughout the year. Here fishes are exposed to ice, and thus their adaptations to avoid freezing are most striking and more easily recognized than they are in temperate-water fishes, which only occasionally encounter ice.

In antarctic nototheniiform fishes, the antifreeze agents are glycoproteins. They are present in eight different sizes (molecular weights range from 2,600 to 33,000 daltons), and have been isolated from all of the body fluids except the urine. They are simple molecules composed of repeating sequences of the glycotripeptide alanyl-alanyl-threonine in which the disaccharide galactosyl-N-acetylgalactosamine is linked to every threonine. The different-sized glycoproteins are made up of differing numbers of this basic unit. The absence of the small glycoproteins in the urine is extremely unusual because, in most vertebrates, the process of urine formation involves filtration of water and small solutes from the blood into the urine by the many glomeruli in the kidney. Inulin filtration experiments and histological studies verified that the antarctic nototheniids are aglomerular and the high levels of glycoprotein antifreeze in their blood (four percent weight/volume) are conserved by this aglomerular condition.

The zoarcid fishes of McMurdo Sound are glomerular and their body fluids are fortified with a protein antifreeze. These protein antifreezes have a molecular weight of 5,000, and they ought to be filtered into the urine but are not. Inulin experiments and morphological studies have led Dr. DeVries and his colleagues to conclude that these fish conserve their antifreeze by turning off the filtration process at the glomeruli. Dr. DeVries and his associate, Dr. Yuan Lin, report this as one of the first clear-cut examples of functional aglomerularism in a marine teleost.

Freezing resistance in fishes of the Bering Sea was also investigated. Graduate student James A. Raymond demonstrated that the saffron cod captured near Nome, Alaska, has a glycoprotein antifreeze which, although similar to the glycoprotein antifreeze of the antarctic nototheniids, is not as effective. It differs in that an arginine residue replaces some of the threonine residues. A sculpin captured near St. Lawrence Island in the Bering Sea was found to have a protein antifreeze which differs from both the antarctic zoarcid and winter flounder protein antifreezes. The fact that different fishes have evolved different antifreezes, both glycoproteins and proteins, is of particular interest; this remarkable adaptation has evolved independently in widespread areas.



A two-year-old sea lion, Houdini, has been trained to follow a moving cart and breathe into gas-collecting apparatus. Above, his swimming effort in Physiological Research Laboratory pool is being measured while he wears a harness equipped with depth-recording instrument. Trainer Dean Druse is a graduate student at San Diego State University.

Dr. Gerald L. Kooyman

All of these antifreeze compounds are being used in studies of the mechanism of antifreeze activity; that is, how do they lower the freezing point in a noncolligative manner? X-ray diffraction and circular dichroism are being done on thin films of freeze-dried antifreeze to determine whether their secondary structure is such that the antifreeze could hydrogen-bond to the surface of ice crystals. It is easy to visualize how coating of ice crystals with antifreeze compounds would interfere with the incorporation of water molecules into the ice lattice of the crystal, and it is conceivable that this may explain the antifreeze effect.

Regulation of body temperature in vertebrates is accomplished by temperature-dependent neurons in the basal forebrain and hypothalamic nuclei. Dr. Harold T. Hammel and his associates continue to investigate how these neurons are affected by sensory inputs from temperature receptors in the skin and from proprioceptors in the muscles and joints, how they are affected by sleep and hibernation, and how they activate behavioral and autonomic thermoregulatory responses.

Thermodes were implanted around neural tissue in the rostral brainstem of harbor seals, Adélie penguins, dogs, and box turtles. Thermoregulatory responses were elicited by altering the temperature of these tissues. Quantitative measurements of these responses, which include shivering, salivation, panting, and increased blood flow to the skin surface, enhance man's understanding of the regulation of body temperature and the evolution of this function in the vertebrate body.

Dr. Werner R. Schmidek, University of São Paulo, Brazil, has been investigating the role sleep plays in altering the regulation of body temperature in cold-acclimated rats. Direct calorimetric measurements of dry and evaporative heat loss and indirect measurements of heat production during slow-wave and rapid eye-movement sleep, and in response to altering experimentally the temperature of the rostral brainstem, provide insights into the complex interaction between sleep and body-temperature regulation. Dr. Kenneth R. Morgareidge has demonstrated that box turtles respond physiologically to experimental alteration of the temperature in the rostral brainstem. Evaporative water loss via salivation can be elicited by heating the rostral brainstem, and the temperature threshold for the response is lowered by increasing the environmental temperature.

Dr. G. James Kenagy has demonstrated that the secretion rate of the lateral nasal gland is influenced by the temperature of the preoptic and anterior hypothalamic nuclei. This gland provides water for moistening the nasal airway of the dog.

Drs. Eckhard Simon and Christa Simon-Opermann, in collaboration with Dr. Hammel, Randall Kaul, and James Maggert, have shown that a thermode in the spinal canal can affect the extent of shivering in the Adélie penguin; *i.e.*, the rate of oxygen consumption is increased by cooling the spinal cord. They had shown previously that cooling the tissue in the rostral brainstem had no effect on shivering, and in repeat experiments were able to demonstrate that cooling the hypothalamic nuclei actually inhibits shivering to an extent depending on the degree of cooling.

Dr. Hammel is investigating the origin of endothermy in mammals. He has suggested that the five-fold-to-tenfold increase in the rate of heat production of mammalian tissue evolved late in the Tertiary and in response to the cooling environment of the advancing Quaternary Ice Age. He also suggests that the high rate of heat production characteristic of tissue from modern mammals would have been counter-productive during the period when all other mammalian features were evolved. With Dr. Kenagy, he is investigating whether a cell organelle, the peroxisome containing oxidases and catalise, is required for the flow of electrons to oxygen in tissue poisoned by cyanide.

Karl Erik Zachariassen, a graduate student from the University of Oslo, Norway, and Dr. Hammel have been investigating the extent of supercooling in tenebrionid beetles from the Mt. Palomar area, in southern California. In many species of *Eleodes*, a substance has been found in their hemolymph that insures spontaneous freezing near the freezing temperature of the fluid. These species tolerate freezing in the winter. By contrast, other tenebrionid beetles cannot tolerate freezing; they lack the substance which enhances spontaneous freezing, and they supercool to about −20°C.

Dr. Edvard A. Hemmingsen continued to study interactions of gases with water and other liquids at high pressure, both in relation to the hyperbaric use of gases by man and to the function of swimbladder in deep-sea fishes. It was of particular interest to him to investigate the spontaneous phase transitions and the subsequent appearance of bubbles in the liquid mass or at various types of interfaces under conditions of gas supersaturation. It was found that, in the absence of preexisting gas nuclei or hydrophobic interfaces, bubbles are produced spontaneously in water only at supersaturations usually exceeding 150-200 atm. By using high-speed, microcinematographic techniques, the phenomena immediately preceding the formation of visible bubbles were recorded for analysis by slow-motion projection. The observed processes differ markedly from any predicted previously, and they promise to have important implications in cavitation hydrodynamics and baromedical physiology.

Investigations of respiratory adaptations in aquatic vertebrates continue to be the major thrust of Dr. Gerald L. Kooyman's research effort. The scope of his work was enhanced this year when the funding for the project was merged with a project of considerable breadth on lung structure and function, which was organized by Dr. John B. West, of the UCSD School of Medicine. These studies deal with the structural nature of the lung and its relation to gas exchange and ventilation. The behavior, physiology, and anatomy of those vertebrates that swim at high speeds and those that dive to great depths are being compared to less-vigorous aquatic forms and terrestrial animals. In addition, a new study of the effects of oil contamination of the pelt on thermoregulation in fur seals was begun in June 1975. This is in cooperation with the Seattle office of the National Marine Fisheries Service.

A series of pulmonary function tests was recently completed on young gray whales in Magdalena Bay, Baja California, in collaboration with Dr. Kenneth S. Norris, UC-Santa Cruz. Similar tests are in progress with trained dolphins and sea lions. The sea-lion research also includes a study of energy requirements at different swimming rates. The sea-lion work is a collaborative effort with Dr. Roger Carpenter, San Diego State University, and two of his graduate students. The data-collection phases of this work are near completion, and included the training of two sea lions to follow a cart around a ring-tank swimming pool. While following the cart, the sea lions were required at each breath to exhale into a tight-fitting cone. This made possible the collection of expired gas samples and the measurement of flow velocities of the expired gases.

The U.S. Marine Mammal Commission helped sponsor the ventilation studies. As part of that study, several moribund animals were collected from local beaches. Efforts to restore them to health were unsuccessful,

and a detailed analysis of the condition of the respiratory system is in progress. Every animal beached has a serious lung ailment that very likely contributed to its death.

Graduate student Everett E. Sinnett began a study on the characteristics of pulmonary blood flow in the harbor seal while the animal is breath-holding and while it is diving. This is a joint effort with Dr. Eric A. Wahrenbrock and others of the UCSD School of Medicine, who, using the same harbor seals, are also assessing the degree of pulmonary shunting that occurs when the seals are dived to various depths. In this way, the amount of lung collapse that occurs because of decompression during deep dives can be quantitatively determined.

Closely related to the pulmonary shunt study of seals is an analysis of gas exchange in yellow-bellied sea snakes and common water snakes when they dive deeply. Much of this work was done at the Smithsonian Tropical Research Marine Laboratory in Panama. The snakes are ideal subjects for comparison with mammals because their lungs and pulmonary vasculature are much simpler.

Dr. A. Aristides Yayanos has made considerable progress this year toward a better understanding of how organisms function at the high pressures of the deep sea. Until now work has been hampered by the unavailability of organisms from the deepest parts of the sea that can function in the laboratory under simulated deep-sea conditions.

Leg 7 of Eurydice Expedition aboard R/V *Thomas Washington* offered an ideal opportunity for obtaining organisms from the Philippine Trench at depths as great as 10,000 m, where the pressure is about 1,000 atm. A device was used that traps amphipods at these depths and returns them to the ship while maintaining them at the pressure of their deep-sea habitat. Eventually this device will be used to study amphipods. The immediate purpose of this sampling program was to use the amphipods as sources of deep-sea bacteria.

Dr. Yayanos' laboratory has succeeded in culturing many amphipod-associated bacteria now growing at the conditions of the high pressure and low temperature of the trench. These cultures offer great promise for providing literally an infinite number of experimental approaches to aspects of the biology of deep-sea creatures.

An important advance has been achieved in his studies of the partial molal volumes of biologically important molecules at high pressures. Accurate data for the specific volume of water are critical for calculating values of partial molal volumes from experimental values of the specific volume of solutions. Dr. Yayanos has been able to corroborate experimentally one of the two claims for the most accurate data on water that have been made in the literature. This gives a greater confidence in the experimental method and data. He is preparing to consider the properties of some of these molecules in seawater.

Dr. Per F. Scholander completed a manuscript with Dr. Hammel entitled, "Tensile Water in Osmotic Processes." The manuscript has been accepted for publication as a book by Springer-Verlag. Dr. Scholander spent the year lecturing and giving demonstrations on this subject in seven localities in Europe. His schedule included his address, as a new foreign member, to the Royal Swedish Academy of Sciences, shortly to be published in the *Journal of Experimental Zoology*.

Visibility Laboratory

Visible light is an important source of information in many kinds of oceanic and atmospheric scientific investigations. The observations may involve cameras; photoelectric systems, such as television; or the human eye, aided by a host of optical devices, including microscopes, telescopes, holograms, and photometers. Because of the importance of these optical means of observation, the Visibility Laboratory conducts a broad spectrum of research related to the propagation of light, both natural and artificial, through water and through the atmosphere, and to the recording of image information by photographic cameras, photoelectric systems, and the human eye. The laboratory also studies the fundamentals of the extraction and interpretation of the received image information.

The following examples illustrate the diversity of current research activities:

Optical Oceanography

Research related to the propagation of light in seawater remains the largest single activity of the Visibility Laboratory. Drs. Seibert Q. Duntley, Raymond C. Smith, Wayne H. Wilson, and Donald E. Silva have continued studies of the physics of the propagation of light in seawater. The experiments, performed in an indoor tank, included use of seawater transported to the facility by tank truck and ordinary tap water to which has been added various ingredients chosen to simulate the scattering and absorbing properties of seawater. Light sources included ordinary tungsten lamps and highly coherent blue-green lasers.

Aboard R/V Ellen B. Scripps *off San Diego, Harry G. Sprink, left, senior electronics technician, and Harry G. Stumpf, oceanographer with the National Environmental Satellite Service of the National Oceanic and Atmospheric Administration, assist in launching newly developed Visibility Laboratory instrument for measuring the optical attenuation and scattering properties in the upper 500 m of the ocean. The instrument measures the volume scattering function at 3, 6, and 12 milliradians from the forward direction and the volume attenuation coefficient. All measurements are performed simultaneously and at any of ten wavelengths selected by the investigator. Control of the instrument and data recording are accomplished by digital telemetry between the underwater instrument and the surface.*

Roswell B. Austin

Roswell W. Austin and Theodore J. Petzold, using instrumentation that they recently developed, have performed a comprehensive study of the attenuation and scattering properties of the water at a site near Santa Catalina Island, off the southern California coast. The measurements, performed with the support of the Naval Electronics Laboratory Center, San Diego, were obtained from a moored barge. They provide an extensive body of data on the spectral nature of these optical properties, their diurnal variations, and their change over a two-month period. The study of these data, obtained at ten wavelengths from 400 to 670 nm, is providing an important insight into the naturally occurring relationships between the volume-scattering function, the total scattering coefficient, and the volume-attenuation coefficient.

The laboratory continued its studies of the oceanographic information that can be extracted from remotely sensed optical data. Under the direction of Austin, improved methods and equipment for acquiring "surface-truth" data from an oceanographic vessel have been developed. Such data provide the pertinent biological, optical, and other physical information on conditions existing in the ocean and the atmosphere that affect the signal available to a remote optical sensor in an aircraft or spacecraft. A field experiment, conducted on R/V *Ellen B. Scripps* operating in southern California coastal waters, provided a preliminary opportunity to evaluate the techniques. An aircraft carrying a specially calibrated four-band, multispectral camera obtained the remotely sensed imagery.

Dr. Smith initiated a study of the body of spectral irradiance data that have been obtained in conjunction with the chlorophyll *a* concentrations and/or primary productivity data. By applying characteristic vector analy-

sis techniques to the irradiance data, he is studying methods of separating the spectral signature into components related to the biogenous and terrigenous constituents of surface waters. If successful, the technique can stipulate the optimum spectral characteristics of remote sensors for detecting chlorophyll-bearing or silt-laden waters and for differentiating between waters having different concentrations of these materials.

A second objective is to devise a new optical-water classification that has a quantitative physical basis related to the magnitude of the several characteristic vectors.

Atmospheric Studies

Fundamental measurements of the optical properties of the atmosphere as they affect natural lighting and visibility were continued from an Air Force C-130 aircraft assigned to the laboratory for this purpose.

The instrumentation of this aircraft has been accomplished over a period of many years. The aircraft and instruments form a sophisticated airborne platform in which a variety of optical and meteorological measurements can be continuously made and recorded by means of a multichannel, magnetic-tape, data-logging system. This permits the aircraft to descend through a stratified atmosphere and obtain a detailed knowledge of the vertical profile of atmospheric properties. The aircraft is usually operated in conjunction with a similarly instrumented ground station, so that corresponding zero altitude data can be added to the vertical profile.

During the past year both the C-130 aircraft and the ground station were sent to Tacoma, Washington, where substantial data were collected in the vicinity of Mt. Rainier.

Research Utilizing Image-Processing Facilities

The computer image-processing research facilities at the laboratory consist of an IBM 360/44 computer, a variety of scanning and display equipment, a unique and versatile computer-program package, and special controls that allow the investigator to interact with the computer. This facility serves several different research activities.

Benjamin L. McGlamery continued his efforts in the development of a computer-simulation system for synthesizing in-water imagery. The system produces photographs that appear as if they were taken in water. The user is able to specify a light source with its angular distribution, a camera type and its location, and the scattering, absorption, and stratification properties of the water. The computer-simulation system mathematically determines how each of these factors alters the image and produces accurate computer-generated pictures showing how any type of underwater scene will appear when photographed by the assumed light-and-camera system. The new simulation capability is an important tool for evaluating existing in-water and light-and-camera combinations, as well as for optimizing the design of new systems. Any proposed in-water camera and lighting system can be given accurate performance trials before it is built, and the suitability of any existing equipment can be ascertained before its deployment.

With the assistance of Dr. Silva, McGlamery also conducted studies of the means of circumventing the image defects imposed by atmospheric turbulence, a limitation to resolution that has long plagued the astronomer. They have been using the simulation capability of image-processing facilities to study the effectiveness of various new techniques in which an attempt is made to deform the optical system in such a way as to compensate for the atmospheric effects.

James L. Harris, Sr., has used the image-processing facilities to study the fundamental physics associated with scattering of light in seawater. The goal of this research is to produce a simulation of the propagation process in which the computer can be asked to characterize the water properties as they would be recorded by any conventional instrumentation, and simultaneously to produce imagery whose quality can be quantitatively evaluated. Such simulation allows any physical property of the process to be varied independently and the effects observed.

Research related to improving the safety of aircraft-landing operations has been continued. Under Harris' direction, studies have continued on the complex process by means of which a pilot extracts from a scene the reference information that he requires to fly his aircraft if visual cues alone are used. An improved understanding of this process may lead to improving the lighting or marking of the runway environment, as well as defining in a more realistic fashion the visibility conditions required for safe landings.

Institute of Geophysics and Planetary Physics

The Institute of Geophysics and Planetary Physics (IGPP) is a University of California systemwide institute with branches at Scripps Institution and the campuses at Los Angeles, Riverside, and Davis. The institute at La Jolla is intimately related to Scripps Institution through its geographical proximity, but more importantly, because of their common scientific interests. Drs. George E. Backus, Freeman J. Gilbert, Richard A. Haubrich, Walter H. Munk, and Robert L. Parker hold joint appointments in IGPP and Scripps. Dr. James N. Brune, Sir Edward C. Bullard, and Dr. Myrl C. Hendershott hold Scripps appointments; their offices are located at IGPP. Dr. Ralph H. Lovberg holds a joint appointment in IGPP and the Department of Physics of UCSD. Drs. Hugh Bradner, John W. Miles, and Gerald A. Frazier hold joint appointments in IGPP and UCSD's Department of Applied Mechanics and Engineering Sciences (AMES). Drs. Jonathan Berger, Brian L. N. Kennett, William A. Prothero, Frank E. Snodgrass, and Gordon O. Williams and Bernard D. Zetler have senior research appointments in the institute. Drs. Christopher Beaumont, Christopher Garrett, and John P. Hunt were visiting Cecil H. and Ida Green Scholars in Earth Sciences. Dr. James L. Cairns is a research associate from the U.S. Naval Undersea Center.

Dr. Bruce continued his involvement with seismic studies in Mexico, studies of the source mechanism of earthquakes, studies of seismic hazard in the San Diego area, modeling the strong motion pattern of earthquakes using a stressed, foam-rubber model, and oceanic seismic studies. With two graduate students from Mexico, Alfonso Reyes and Alejandro Nava, and in cooperation with Dr. Cinna Lomnitz of the National University of Mexico, Mexico City, and Fred Mooser of the Mexican Federal Power Commission, Dr. Brune and his group carried out field studies and initiated a permanent seismic array in the Colorado Delta area of Mexico. A new cooperative effort has begun with the seismology branch of the Centro de Investigación Científica y Educación Superior de Ensenada (CICESE). In association with Drs. Prothero and Bradner and several graduate students, Dr. Brune has continued ocean seismic studies, using both ocean-bottom seismographs and sonobuoys. In order to understand the pattern of strong motion expected around major earthquakes, a foam-rubber model has been set up with dislocations that, when stressed, slip in the same manner as earthquakes. In this way, the maximum particle velocities and accelerations are related to other parameters of the dislocation; for example, the stress drop and rupture velocity. In collaboration with Dr. Gilbert A. Hegemier of AMES and Dr. Frazier, Dr. Brune is comparing the model data with results of numerical methods.

Dr. Frazier has been engaged in the development and adaptation of computer techniques for numerically simulating earthquake processes. Computer schemes, based on the finite element method, have been employed to model crustal deformations in southern California, subsidence and earthquake initiation at the Wilmington Oil Field in Long Beach, and ground motions produced by the 1971 San Fernando earthquake. Current research is attempting to establish relationships between strong ground shaking and earthquake ruptures by employing 3-D computer models.

Sir Edward Bullard has continued his work to revise the reassembly of the continents around the North Atlantic to positions they occupied before the opening of the Atlantic and on the dynamo theory. He has recently written a number of papers on the history of earth science during the last 50 years.

In Dr. Gilbert's Project IDA (International Deployment of Accelerometers), a global array of digitally recording LaCoste-Romberg gravimeters (with Dr. Jonathan Berger), were installed at Canberra, Australia, and in the village of Nana, near Lima, Peru. His research also included (1) the effect of small, aspherical perturbations on travel times has been studied theoretically and a reexamination of the corrections for ellipticity has been made (with Adam Dziewonski of the Hoffman Laboratory, Harvard University); (2) the Rayleigh-Ritz method has been applied to the calculation of the earth's normal mode eigenfrequencies and eigenfunctions (with Scripps graduate student Raymond Buland); (3) some asymptotic properties of the earth's normal modes have been found that clarify the ray-mode correspondence; (4) an exact traveling-wave representation of seismic displacements has been derived for use in the study of regional structure; and (5) differential kernels for group velocity have been derived and will be used to interpret new mantle overtone data.

Dr. Kennett (supported by a Lindemann Trust Fellowship) developed efficient procedures for the calculation of synthetic seismographs for realistic earth models; these have been used to examine the effects of attenua-

tion within the earth on the recovery of structural information from seismic waveforms and also to look directly for the effects of precursive compression for deep earthquakes. A comparative study has been made of methods of inverting travel-time data for seismic refraction profiles. With John A. Orcutt, Scripps graduate student, and Dr. LeRoy M. Dorman, a combination of these techniques has been applied to studying the oceanic crust at the East Pacific Rise, using refraction profiles. This work has provided good evidence for a low velocity zone (magma chamber?) beneath the rise crest.

Dr. Parker's work on the interpretation of gravity data has led to a general theory for providing bounds on permissible solutions to linear inverse problems; it has become clear that a purely linear theory is always inadequate and that the introduction of a nonlinear element is essential in any inverse problem with limited data. For several years Dr. Parker has been working with Dr. John D. Mudie of the Marine Physical Laboratory and Scripps graduate students Stephen P. Huestis and Kim D. Klitgord, on the analysis of near-bottom magnetic records in the Pacific. This project is now complete. Models of magnetization were produced in several widely separated regions and, on interpretation of the models, yielded some exciting conclusions. A principal one was that the crustal generation process appears to create sea floor at an astonishingly constant velocity (constant to ±3 percent) for periods of 1-2 million years, sporadically undergoing abrupt accelerations that can change the velocity by up to a factor of two. All the ridges in the study experienced between one and four such accelerations in the last six million years.

Dr. Berger continued studies on the seismotectonics of southern California, using data from Piñon Flat Geophysical Observatory, near Palm Springs, as well as geodetic data obtained from NASA's project SAFE (San Andreas Fault Experiment) and the geodetic nets of the USGS (U.S. Geological Survey). In collaboration with Dr. Christopher Beaumont, studies have been conducted on the effects of lateral heterogeneities in the crust on the earth and ocean tides. The effects of topography, geology, and mine cavities have been examined in detail for seven strain observatories in the continental United States.

Dr. Lovberg and UCSD physics graduate student Prabhakar P. Tripathi have completed work in the mode-locked laser strain meter. At this point, it has been demonstrated that the concept is feasible in that a pulsating beam, suitable for base-line measurement through frequency counting, has been achieved. However, before the system is suitable for field application as a geophysical strain meter it will have to be improved in several respects, principally higher laser gain and lower loss optics.

In physical oceanography, Drs. Munk, Snodgrass, Williams, Cairns, and Garrett, and Zetler and Worcester continued microstructure and internal wave studies using a "yo-yoing" mid-water capsule, concluded research involving MODE (Mid-Ocean Dynamics Experiment) data, and initiated experiments on the effect of environmental parameters on acoustic transmissions. Results from spectral analysis of exceptionally clean, long, internal-wave records have greatly restrained the free parameters in internal-wave models; lenses of high microstructure activity (globs) have been identified and some have been found to be associated with intrusions. Unexpected response of a passive capsule to internal waves led to capsule dynamics experiments in the Pacific Ocean and in Lake Tahoe.

Results from analysis of MODE bottom pressures make it possible now to furnish ground (sea) truth for spacecraft laser altimetry in the GEOS-C (Geodynamics Experimental Ocean Satellite-C), (NASA) experiment. A study of oceanic-acoustic interactions in a mid-ocean geometry was initiated using one-way acoustic transmissions; in related research, the statistics of multipath scintillations for a two-time series of acoustic signals between Eleuthera, in the Bahama Islands, and Bermuda have been interpreted in terms of internal waves and tides.

Dr. Miles completed studies of the asymptotic solution of Laplace's tidal equations and (in connection with this work) of both the prolate and oblate spheroidal wave functions. He is continuing work on nonlinear surface waves in closed basins and has shown how such problems can be transformed to equivalent problems in classical mechanics, thereby rendering available the methods of Hamilton and Poincaré.

Dr. Backus obtained theoretical stability criteria for thermal runaway in a viscous medium with temperature-dependent viscosity. He also derived the inequalities that govern the gross thermodynamics of the heat "engines" that produce the geomagnetic field and continental drift. Because the electrical or mechanical activity is dissipated as heat within the system, ohmic or viscous heating can, in principal, be greater than the radioactive heating that drives the motions. Finally, he cataloged the different kinds of seismic moment tensors and gave them a direct physical interpretation. A principal conclusion of this work is a theoretical justification for the use of generalized moment tensors to represent all seismic sources not involving interaction with bodies outside the earth.

Dr. Haubrich's investigation of the excitation sources of the Chandler wobble has continued. Known meteorological variations in both oceans and atmosphere have been found to account for most of the Chandler wobble, as well as for a peak at one cycle per year in the spectrum of gravity observations. Air-mass variations could well be the most important excitation source. His examination of spectrum analysis methods has revealed some interesting fallacies concerning "high resolution" spectral estimates.

Dr. Hunt's research centered on attempting to understand and define both the man-made and natural limits to the earth's mineral resources, especially copper. An interdisciplinary workshop at IGPP on "Future Nonfuel Mineral Supplies" was an integral part of this effort. Results of the workshop indicated that future mineral supplies, including copper, will depend primarily on man's ability (technical, economic, social, and political) to utilize natural resources, rather than the actual size of resources. The actual size of mineral resources cannot be predicted quantitatively with present knowledge. The case of copper resources was considered as an example. Consideration of the geochemical affinity of copper for sulfur suggests that copper resources are much larger (by more than one order of magnitude) than estimates based on past mining and exploration experience would suggest.

Institute of Marine Resources

The Institute of Marine Resources (IMR) is charged with research, education, and public service in the broad area of marine resources utilization. IMR provides a basis for studies to improve the nation's supply of organic and mineral materials, to harness energy from the sea, and to extend

The Scripps-designed and developed tethered-float breakwater (TFB) went from the laboratory into actual use in San Diego Bay during the year, as is evident from photo taken off Naval Undersea Center during news conference at which developers – the Navy's Naval Facilities Engineering Command and California Department of Navigation and Ocean Development – took their first look at actual performance of breakwater. Test showed a 60 percent reduction in waves. Model is designed to provide shelter from wind- and boat-generated waves in inland waters. Prior to demonstration, Professor John D. Isaacs, TFB designer, left, and Dr. Charles J. Merdinger, deputy director of Scripps, examine array of floats attached to a module, 19 of which were utilized in bay testing to form 46-m-long, 6-m-wide breakwater. Plans call for testing breakwater in open ocean.
U.S. Navy

knowledge about other resource issues such as recreation, transportation, pollution, and waste disposal at sea. IMR also provides for research into the social, legal, economic, and political aspects of man's related marine activities.

IMR, which has facilities on the Davis and San Diego campuses of the University of California, is administered from Scripps under John D. Isaacs, director. Assisting the director on policy and research plans are an advisory council staffed by public members appointed by the president of the university, and an executive committee staffed by faculty members.

A brief account of the principal IMR activities at Scripps follows, including those of the Food Chain Research Group (FCRG), of the Center for Marine Affairs (CMA), and of that part of the Sea Grant College Program that is undertaken at Scripps. A full description of research is published in the periodic reports of IMR, FCRG, and Sea Grant.

Marine Food Chain Research

The Food Chain Research Group studies the abundance of components of the marine pelagic food web and the food and energy transfers between the components, including bacteria, phytoplankton, and zooplankton, and the biologically-active dissolved compounds (nutrients, trace metals, and organic molecules). These two major efforts combine laboratory studies on the physiology and biochemistry of plankton with field studies of distribution, and with the development of analytical techniques for *in situ* and laboratory measurements of food chain components.

The main field program of FCRG consists of a survey of plankton and chemical and physical properties in the Southern California Bight, because the coastal zone is not as well understood as the offshore California Current, and because man's interests are strongly represented in this zone, which receives much of his impacts. In a grid of stations visited quarterly, nutrients, trace metals, such as copper; phytoplankton, microzooplankton, macrozooplankton, and larval fish are sampled, and primary productivity and heterotrophic activity measured. In addition to learning basic properties of the area being surveyed, man has been able to answer certain specific questions.

For example, the deleterious effect on phytoplankton of chlorine used in the cooling-water system of the San Onofre Nuclear Power Plant, in southern California, appears to be confined to the immediate area of the outfall, with no indication of far-field residual effects.

Other FCRG work includes the determination of the distribution and abundance of phytoplankton and particulate organic matter in the Antarctic Ocean; assessment of the importance of photorespiration in primary productivity measurements; and use of ^{68}Ge to study the silicon metabolism of diatoms. Studies continued on the detailed biochemical composition of phytoplankton and of diel periodicity in growth; determination of the microbial biomass and activity in deep-sea bottom waters and sediments, especially with regard to the effect of pressure; and on improvement of analyses for amino acids and of measurements of submarine illumination.

FCRG research progressed on the nitrogen metabolism of dinoflagellates with respect to their dielmigration, and investigation of the abundance, depth distribution, and seasonal cycle of plankton in the central North Pacific. Development of a holographic system for studying behavior of zooplankton continued as well as a field study of the small-scale patchiness of juvenile copepods and their food. The deep-tank program used a 70-m^3 tank for assessing energy transfers between selected phytoplankton-zooplankton populations. Several FCRG scientists took part in the multiinstitutional CEPEX (Controlled Ecosystem Pollution Experiment) study on the effects of pollutants on natural plankton assemblages contained in 65- and 2,250-m^3 plastic columns.

Center for Marine Affairs

The center held a workshop on "The Management of Marine and Coastal Resources in Baja California: Research Needs and Priorities," attended by several high-ranking officials of the Mexican government, including Dr. Leopoldo Solis, economic advisor to the President of Mexico. Mexican scientists and social scientists and their counterparts from several American universities, foundations, and institutions also participated. The main topics discussed at the workshop included new directions in Mexican national economic policy, regional planning, and the development of Baja California. Topics in the Baja California development discussion concerned fisheries and aquaculture, tourism and its impact and management in the coastal zone, and social science research needs for conservation development of the Baja California marine resources.

Dr. Paul I. Mandell continued his studies of the northern anchovy. He is concerned with the problems posed by a developing anchovy fishery in Mexico adjacent to a quiescent anchovy fishery along the California coast. Since a population of anchovies extends across international boundaries, cooperative management of the fishery is necessary for wise utilization of this resource.

Dr. Jack N. Barkenbus explored the international implications of deep-sea mining, in particular, manganese nodules. He is investigating the political regimes that will allow maximum use of this resource.

Dr. Emmit B. Evans is developing the theoretical background for investigating the role of science in the development process of Baja California and other areas. In the field, he is concentrating on oceanography in Mexico.

CMA members attended meetings in Washington, D.C., sponsored by the National Science Foundation to develop interdisciplinary research programs in oceanography.

Sea Grant College Program at Scripps

The University of California Sea Grant College Program, headquartered at Scripps, is administered by IMR. Policy guidance for the program is vested in the IMR advisory council; administrative advice and program review rests in the IMR executive subcommittee for Sea Grant.

In its mission to obtain the wisest utilization of the resources of the sea and defend against its hazards, through research, education, and public service, Sea Grant supports 41 projects and 60 graduate trainees on California campuses; at Scripps, they number 12 and 18, respectively. Brief highlights of the 12 projects follow. More detailed summaries are included elsewhere in this *SIO Annual Report*.

"Ocean Education for the Public," a program under Donald W. Wilkie, has involved more than 57,000 students in its group-education projects. The program sponsored the "Fourth Annual Symposium for Teachers on Marine Mammals," and a pilot program for docents to visit schools that were unable to bring students to the aquarium-museum; it provided career experience for outstanding students in biology and aquariology; and it opened a unique tide-pool exhibit to enhance the teaching of conservation measures in the intertidal zone.

Under Dr. Douglas L. Inman's study "Physical Criteria for Coastal Planning," guideline documents for coastal engineering planning are being prepared. This project will culminate in the publishing of a handbook that sets down criteria for coastal engineering planning decisions. The handbook will be available from Sea Grant.

Dr. Paul K. Dayton's "Ecological Studies of the Nearshore Zone" provides information needed by coastal planners and resource managers in determining possible effects of man's activities in the coastal zone and in distinguishing these from natural variation. The study advises those concerned with harvesting natural populations along the nearshore regarding consequences of harvest and pest-control techniques, and furnishes baseline data and general information to the advisory committee of the San Diego-La Jolla Underwater Park.

Dr. Dayton is also project leader for a program entitled "Studies Toward the Optimal Management of Sea-Urchin Fisheries." This program provides information to such regulatory agencies as the California Department of Fish and Game, on coastal sea-urchin fisheries; to coastal planners; and to fishermen themselves, especially those harvesting urchins, abalone, and algae.

The research project "Use of Thermal Effluent in Aquaculture" is being conducted by Dr. Richard F. Ford and Jon C. Van Olst of San Diego State University. A portion of their research work is being conducted at Scripps. It is hoped the project will contribute directly to the successful development of a lobster-farming industry through evaluation of a pilot production module. Use of essentially cost-free waste heat in power plant thermal effluent (from the San Diego Gas and Electric plant in Carlsbad, California) to accelerate growth and reduce production time shows promise as a means of attaining economically viable lobster culture.

Dr. Francis T. Haxo's "Mass Culture of Toxic Dinoflagellates" provides a varied and reliable source of microorganisms for chemical studies by Dr. Henry Rapoport (UC Berkeley) to develop a dependable test for saxitoxin and other dinoflagellate toxins for assessment of toxicity in resident marine life, especially shellfish.

Under Dr. James J. Sullivan, UCSD graduate students Michael K. Orbach and Tracy R. Lewis, working in the Marine Resources Management Intern Research Program, have focused on the social-science issues inherent in fisheries management. In cooperation with scientists from the La Jolla-based Southwest Fisheries Center, Dr. Sullivan and the students studied the management of the eastern Pacific tuna fishery utilizing both field work with the San Diego-based tuna fleet and laboratory development

of a tuna-demand model. The studies led to simulations of alternative management strategies.

Dr. D. John Faulkner's "Marine Natural Products Chemistry" project has sought a natural marine compound to control the growth and reproduction of fouling organisms in an effort to develop less toxic coatings to replace the heavy metal coatings currently employed in anti-fouling paints. The project established a screen for compounds active against marine bacteria. Extracts of organisms, particularly red algae, were tested for their activity against both marine and pathogenic bacteria.

The study, "Seaweed Products: Applications in Algae Control, Mariculture, and Agriculture," under Dr. William H. Fenical, utilizes bioassay techniques to isolate products that inhibit algal growth; assesses natural antimicrobial agents that control disease in crustacean mariculture; and tests halogenated substances from algae in assays used for agriculture pests. "Active substances" from more than 15 species of algae have already been isolated and identified.

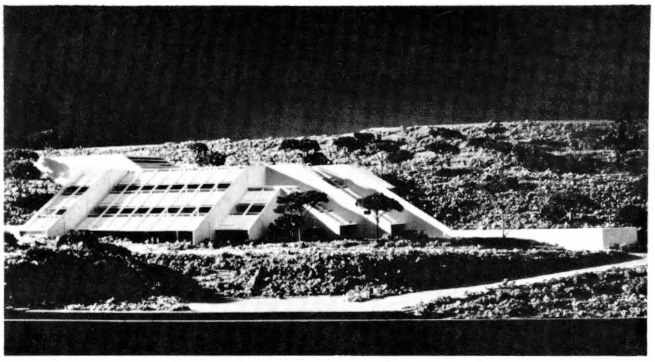
Dr. Fenical is also the leader for the project, "Naturally Occurring Halogenated Compounds: an Assessment of Their Interference in Pesticide Pollution Analysis." This project describes new methods of pesticide analysis for marine environmental investigations.

John D. Isaacs is project leader for the study, "Wave Climate Modification in Harbors by Dynamic Breakwater." Results of this investigation are already being employed by coastal engineers and harbor and shore protection designers to evaluate, plan, price, and design tethered-float wave attenuation systems. With the support of the U.S. Navy and the California Department of Navigation and Ocean Development, several breakwater systems have been tested off the California coast and in San Diego Bay. At Scripps, instrumentation has been developed to collect wave data and measure the wave attenuation of these floating breakwaters.

The "New Applied Developments" project, also directed by Isaacs, provides an opportunity to engage in exploratory tests and experiments of potentially important new ideas as they emerge. Recent projects have examined anisotropic sand flow in harbors for reducing the cost of shipping-channel maintenance, a preliminary assessment of the global mean wave energy, and the performance of a wave-powered pump model in the elaboration of a viable, wave-energy, conversion device, and the development of an easy-to-use, inexpensive drop camera for studying schools of pelagic fish.

Additional Activities and Services

This year IMR supported 21 graduate students in research related to the mission of the institute. Three of these projects resulted in dissertations: on the temperature adaptation of the fish genus *Gibbonsia*, on the diversity of the macrobenthos in two bathyal communities, and on the dynamics of phosphate utilization by marine phytoplankton. Abstracts of these dissertations and of the student research appear in the *IMR Biennial Report*, available from the institute on request. That report also lists the *IMR Reference Series, q.v.*, and the *IMR Technical Report Series, q.v.*



Model shows design for the new, $2.5-million Scripps Library. Ground breaking for the three-story, reinforced-concrete structure is scheduled for July 1975, with completion in late 1976. The nearly 32,000-square-foot building will be lodged deep in the campus hillside at a site north of Scripps's main complex of buildings.

SHORE FACILITIES AND COLLECTIONS

The facilities and collections described below are keyed numerically to the accompanying campus map, except where they are indicated as being located elsewhere.

Facilities

Thomas Wayland Vaughan Aquarium-Museum (5). The aquarium-museum is devoted to increasing the public understanding and appreciation of the ocean sciences through exhibits of living marine animals, museum exhibits, and a variety of educational programs. Important public information service is also provided through responses to written, telephone, and face-to-face inquiries.

The staff, assisted by nearly 60 volunteer docents, conducts a manifold educational program. In the major program, more than 57,000 students annually tour the aquarium-museum in educational groups. Other offerings include summer-school classes, Junior Oceanographers Corps, in-service training for teachers, and a career-experience program for high school and college students considering an aquarium or marine biology career. Federal Sea Grant funds support a full-time coordinator for educational programs.

Research is carried out on problems centering around maintenance systems for marine animals, coloration in fishes, and fish diseases. Research support is also provided through consultation. Through the collecting facility operated by the aquarium, several thousand specimens are collected annually for Scripps researchers and instructors.

During 1974-75 some new museum exhibits, expansion of educational programs, and an exhibit designer were supported by gifts pledged to the Foundation for Ocean Research by the Southern California First National Bank (SCFNB) for the benefit of the aquarium-museum.

A major new exhibit that opened in 1975, the 3x6-m tide-pool exhibit, was funded by SCFNB and Mrs. Theodora H. Ives of Las Vegas. The tide pool, first of its kind ever to be constructed, features rising and falling tides, on an abbreviated two-hour cycle, and wave action, which is generated at various periods by a wave vacuum chamber that was conceived and designed by John Powell of the Hydraulics Laboratory. The time and duration of the wave surges and the tidal cycle can be widely varied, to accommodate research and/or as dictated by visitor response.

Although admission to the aquarium-museum is free, voluntary contributions from many of the more than 350,000 yearly visitors provide significant financial support. The aquarium-museum is open to the public daily.

The aquarium-museum bookshop specializes in oceanographic literature, and selections vary from highly technical and scientific works to a variety of children's books and general-interest materials.

Analytical Facility (7) and (11). The facility was organized five years ago to provide the Scripps graduate student and staff with analytical instruments and professional assistance to aid in thesis or project research. Capabilities of the facility include an X-ray diffractometer for crystal lattice parameter and mineral identification; X-ray spectrometer for qualitative and quantitative analysis of elements above atomic number 12; atomic absorption spectrometer (A.A.) for quantitative determination of elements in solution; heated graphite atomizer (attachment to A.A.) for determination of elements in solids with detection limits of 1×10^{-12} grams; amino-acid analyzer for amino-acid characterization; gas chromatograph for separation and identification of molecules in the gas phase; gas chromatograph/mass spectrometer for qualitative separation and analysis of organic compounds; a Nova 1210 mini-computer for data handling; carbon-dioxide analyzer for sample carbon and carbonate content in terms of carbon dioxide; a Cambridge S4 scanning electron microscope for examination of samples at magnifications up to 100,000X enhanced by a depth of field far surpassing the light microscope; and two Siemens electron microscopes, together with freeze-etching (Balzers) and accessory equipment, provide high resolution in the study of ultra-fine structure. The facility offers complete sample preparation laboratories (including "wet" chemistry and rock processing laboratories, a table-top Olivetti computer, and geological field equipment).

Cardiovascular Research Facility (13) Established in 1965 as a joint enterprise of Scripps Institution's Physiological Research Laboratory and Scripps Clinic and Research Foundation, La Jolla, this facility consists of an experimental animal colony, equipment for physiological research involving measurements of circulatory and cardiac functions in free-moving animals, and a Cardiovascular Instrumentation Development Laboratory in

All geared up for a dive near Scripps Pier is James R. Stewart, diving officer. He has been a SCUBA diver since 1953, and heads program of diver training that has compiled a 13-year record of more than 59,000 accident-free dives by faculty, staff, and students and federal, state, and local government employees who have trained at Scripps.

Photo by Jerry Windle, courtesy of San Diego Evening Tribune

Nestled in a 3x6-m beach scene of sand, rock, and pilings in front of the institution's Vaughan Aquarium-Museum is the first tide-pool exhibit to offer visitors an opportunity to observe a variety of tide-pool plants and animals in a habitat that simulates tide changes, waves, and even rock formations. Through the use of a vacuum-chamber wave generator, waves are produced at 8-to-10-second intervals while the water level is being raised and lowered. Timing of the tide changes can be varied; originally it was set for four-hour cycles. Rocks for the tide pool were formed by pouring concrete into latex molds taken from rock formations in the intertidal zone on the Scripps beach. More than 50 aquarium-museum exhibits are open to the public, without charge, from 9 a.m. to 5 p.m. daily.

support of physiological research.

Diving Facility (16). The diving facility contains showers, dressing rooms, diving equipment storage, air compressors, a 1,113-*l* air volume bank, diving cylinder storage, and an overhaul and repair facility. An 11-m diving boat and a 5-m skiff are available to the diving facility.

Scripps's SCUBA diver-training program, among the oldest diver-training and scientific diving programs in the country, conducts a number of SCUBA training classes annually. These are generally limited to UCSD personnel who have the need to work or study underwater, but federal, state, and local government employees may be admitted by special permission. Some 100 faculty and staff members and students are certified for underwater work; they make an average of 4,000 dives a year. The institution has a 13-year total of more than 59,000 accident-free dives.

Electron Microprobe Laboratory (11). This laboratory handles the chemical analysis of volumes as small as one cubic micron at concentration levels above a few hundred parts per million. This is achieved by accurate spectrographic measurements of the X-radiation from the area analyzed, which is excited by a focused electron beam. The instrumentation is used primarily in studies of mineralogical, petrological, and solid-state physical problems.

Experimental Aquarium (6). Used by faculty, research staff, and graduate students for various studies (such as fish culture), this aquarium is provided with seawater and is equipped with 5 rooms for controlled environmental studies, 17 tanks, and 8 seawater tables.

Hydraulics Laboratory (1). This laboratory is equipped with a wind-wave channel 43x2.4x2.4 m in size with a simulated beach and a tow cart for instrument and model towing; a 15x18-m wave-and-tidal basin with an adjustable simulated beach; a 40-m, glass-walled, wave-and-current channel; a granular fluid mechanics test facility consisting of a 6x12x3-m-deep concrete basin; a 10x1x1-m fludizing channel; three sand storage and calibration tanks each 4 m high x 5 m in diameter, all serviced with a high-flow, slurry, pumping system; and an insulated, refrigerated, cylindrical seawater tank 10 m deep and 3 m in diameter used for various physical and biological studies. All wave generators in the laboratory are programable and can be computer controlled. An IBM 1130 computer system is the central controller for data acquisition and data processing in conjunction with experimental use of the various facilities.

Kendall-Frost Mission Bay Marsh Reserve (Mission Bay, San Diego). Approximately 20 acres of marshland in Mission Bay belonging to the university constitute a marsh preserve and wildlife refuge designated for teaching and research, as one unit of the University of California Natural Land and Water Reserve System. Surrounding tidal and shoal waters have been designated by the City of San Diego to be retained in a natural condition. The reserve has been used frequently for teaching and research by UCSD and other California colleges, and construction of a laboratory has been planned.

Marine Science Development and Outfitting Shop (10). This shop is equipped with precision tools and has a staff of toolmakers and diemakers who participate in the design, development, and fabrication of research equipment and instrumentation in support of the various laboratories at Scripps, the Southwest Fisheries Center — National Marine Fisheries Service, UCSD, the Scripps fleet, and other educational and governmental organizations throughout the United States.

Mass Spectrographic Equipment (7) and (11). Eight mass spectrometers are available, including two 15-cm. Nier-type spectrometers for isotopic analysis of light elements; a 15-cm, Nier-type spectrometer for rare gases; a 25.4-cm double-collection mass spectrometer for He^3/He^4 ratio measurements; a Gas Chromatograph-Quadrupole Mass Spectrometer for qualitative separation and analysis of organic compounds; a 30-cm-radius, solid-source, mass spectrometer for geochronology and isotope dilution analysis; and two units for respiratory gas analysis.

Mt. Soledad Laboratory for Marine Radioactivity Studies (3 km south of Scripps campus). This laboratory, because of its highly specialized equipment and its isolation from other research areas where relatively large amounts of radioactivity are employed, provides for the study of the natural radioactive background in the ocean. It also provides for the detection and measurement of minute traces of artificial radioactivities that are entering the ocean and accumulating in many of its organisms as a result of weapon tests and the industrial and research use of nuclear materials. These studies yield information needed for predicting the impact expected from increased use of nuclear fuels in the future. This facility is continually expanding its capabilities for analyzing numerous biological samples for plutonium and other alpha emitters. A high-precision, computer-controlled, flame spectrometer is employed to study nonradioactive traces of natural cesium and other alkaline metals in the ocean.

Petrological Laboratory (8). With a staff of two and currently administered through the Geological Research Division, this facility provides thin-sectioning, microprobe sample preparation, and rock surfacing services to staff and students of Scripps Institution and associated instructional groups. All types of submarine and subaerial igneous, metamorphic, and sedimentary materials, in various states of lithification, are prepared here for microscopic study by researchers.

Physiological Research Laboratory Pool Facility (4). This facility consists of a holding pool for large marine mammals and fish; a ring pool of 10-m radius equipped with a variable speed trolley carrying instruments for various hydrodynamic and biological studies of mammals and man; and a behavioral pool for echo-location studies and animal training. A central island within the ring pool contains small, dry laboratories and a "wet"

Sitting on Scripps Pier flume that brings seawater to Vaughan Aquarium-Museum and campus laboratories, Associate Director Dr. George G. Shor, Jr., pointing, explains institution's seawater delivery system to International Science Fair participants who were awarded tours of San Diego science-oriented facilities as culmination of national competition. The ISF-winning students received this special recognition from both the American Geophysical Union and the U.S. Navy.

Jackie Janke

Speaking before representatives of campus and community, Don Wilkie, director of Vaughan Aquarium-Museum, center, speaks during dedication of two new aquarium-museum exhibits – an onshore tide pool, at which dedication was held, and an exhibition of Scripps's rare "four-legged" coelacanth fish. Other participants were, from left, UCSD Chancellor Dr. William D. McElroy; San Diego Mayor Pete Wilson; Scripps Director Dr. William A. Nierenberg, master of ceremonies; and Alan Lord, regional vice-president of Southern California First National Bank, a major contributor to the tide-pool project.

laboratory equipped to handle large animals. A flow channel through the island permits transfer of animals from the ring pool into the laboratory. The ring pool was used in 1974-75 for energy consumption studies with swimming and diving sea lions.

Radio Station WWD (14). Licensed to the National Marine Fisheries Service and operated by Scripps personnel, Station WWD provides communications services to both organizations as well as to other governmental and institutional ships; weather advisories to the fishing fleet, scientific, and operational traffic. The station has worldwide capabilities. Voice CW, radio-teletype, and facsimile transmissions can be handled by the station, which operates 12 hours a day Monday through Friday, and 8 hours a day on Saturday, Sunday, and holidays.

San Vicente Lake Calibration Facility (48 km northeast of San Diego). This facility, operated by the Marine Physical Laboratory, is equipped for testing and calibrating acoustic transducers used in oceanographic research. The equipment is located on an 8x15-m enclosed platform in 40 m of water, offering 1,372 m of unobstructed range.

Seawater System (15). The system provides seawater to Scripps and the Southwest Fisheries Center. It utilizes two sand filter beds and two concrete storage tanks, with a total capacity of 442,845 *l*. Delivery capacity is about 5,300 *l* per minute with a normal delivery of about 2,650 *l* per minute.

Scripps Library (8). The library houses a vast amount of oceanographic information with outstanding collections in oceanography, marine biology, and undersea technology. In addition to a basic collection of monographs and serials in mathematics, physics, chemistry, geology, and zoology, the main collection includes extensive expedition literature. As of June 30, 1975, the library held 107,377 bound volumes; 25,945 maps and charts; 20,611 reprints; 25,046 documents, reports, and translations; and 3,361 pieces of microcopy. The Documents/Reports/Translations Collection is comprised of a nucleus of technical reports and memoranda issued by Scripps and supplemented by reports and translations issued by other educational, governmental, and industrial institutions involved in marine research. The Map and Chart Collection is a reference collection of atlases, nautical charts, and geologic and topographic maps. The collection emphasizes nautical information, and is a depository for U.S. Geological Survey geologic maps and related publications. The library's Rare Book Collection has many old and valuable treatises and encyclopedias in science and natural history, as well as numerous accounts and journals of famous voyages of discovery.

Scripps Pier (15). A familiar landmark is the 305-m Scripps Pier, built in 1915 as a platform for serial observations, data gathering, and scientific work. Sea temperature and salinity observations have been made daily since August 1916, from instruments housed at the pier's seaward end. Here also an automatic gauge records tidal fluctuations, and pumps deliver the seawater used in laboratories and aquariums of Scripps and the Southwest Fisheries Center.

Shipboard Computer Group (7). This group of computer programers, engineers, and technicians supports four IBM 1800 computers and, as required, other computer systems at Scripps through programing, interface design, and maintenance. Computers are installed permanently on R/V *Thomas Washington* and R/V *Melville* and ashore in Ritter Hall.

The computer systems are equipped with printers, card readers, typers, plotters, disk memories, and magnetic tape units for batch-processing and real-time data storage, processing, and display. They are interfaced to a ship's course and speed and satellite navigation receivers for precise determination of data location. Scientific instruments interfaced to the computer for automatic data acquisition and storage include STD (Salinity-Temperature-Depth probe), XBT (Expendable Bathythermograph), magnetometer, transponder-ranging inputs for the Marine Physical Laboratory's Deep-Tow vehicle, and radio-relayed, sonobuoy, seismic-refraction and wide-angle reflection signals.

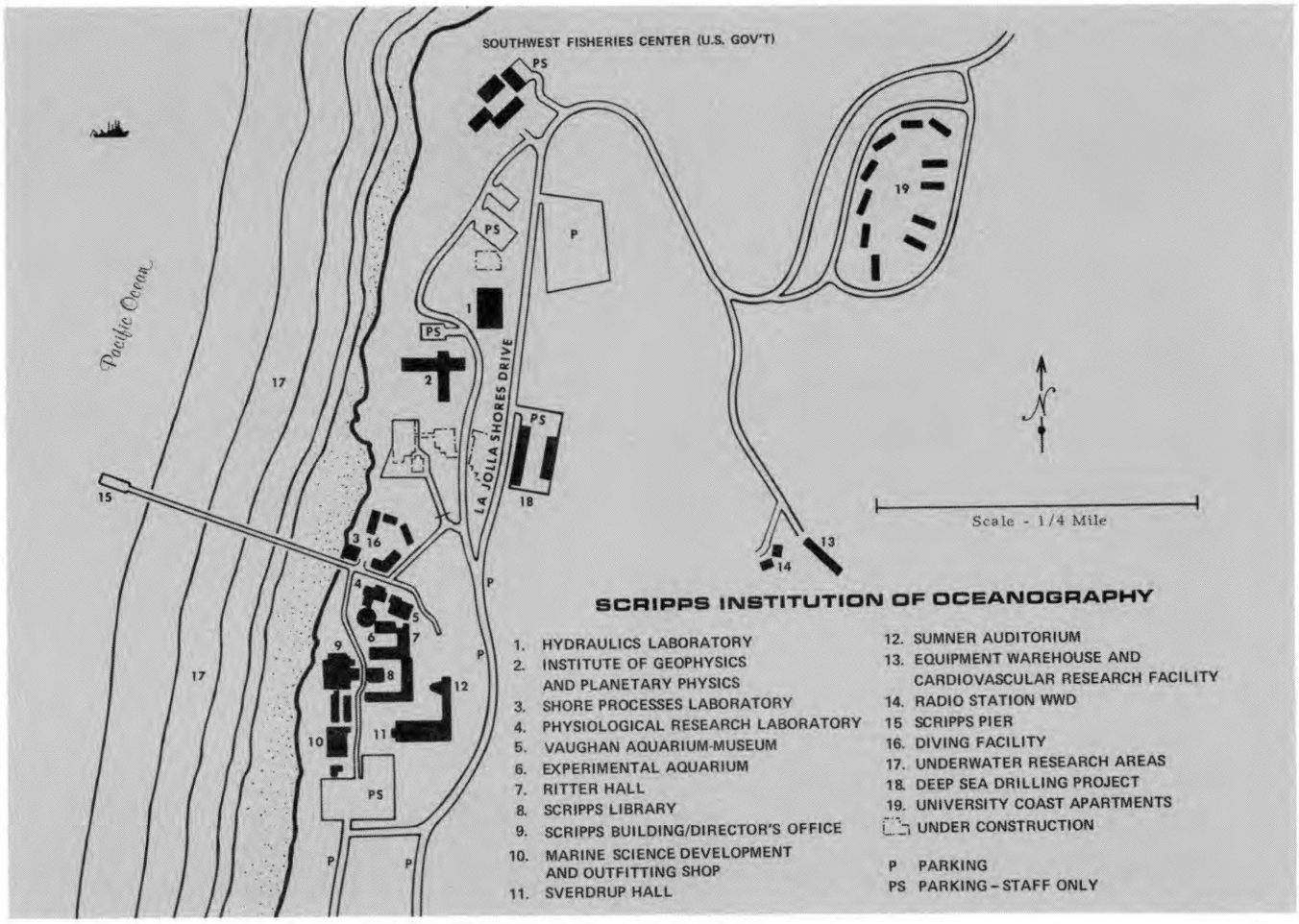
Data are routinely stored on disk and magnetic tapes for return to Scripps, and they may be processed, correlated by time or position, and displayed numerically or graphically, at sea and ashore.

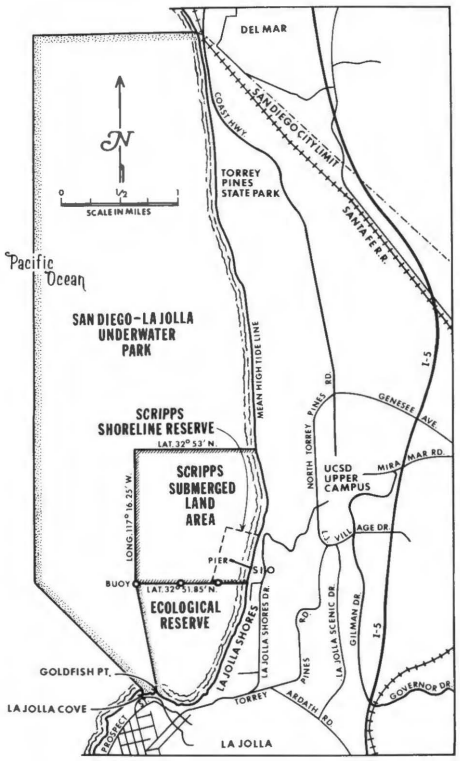
Shore Processes Laboratory (3). The Shore Processes Laboratory is the research facility utilized by the Shore Processes Study Group, whose principal interest is the investigation of the nearshore environment. The structure, a 270-m^2, multipurpose building, includes office, laboratory, and shop space. An electronics laboratory and mechanical shop within the building are used for fabricating and maintaining instrumentation. The laboratory houses data acquisition and processing equipment, including a shore receiving station for telemetered data, analog and digital magnetic tape recorders, and strip-chart recorders. Data processing is achieved with an Interdata Model 70 computer equipped with a disk storage unit, digital tape recorders, a paper tape recorder, graphic plotter, and CRT terminal. The laboratory includes a library that contains an extensive collection of reference material on coastal-zone processes and a collection of nearshore sediment samples.

Southwest Regional Calibration Center (Off campus, in San Diego). This facility, a branch of the National Oceanographic Instrumentation Center, is operated by the Marine Physical Laboratory under contract with the National Oceanic and Atmospheric Administration. Work of SRCC, which is equipped to calibrate oceanographic instrumentation for governmental and non-governmental research, concentrates mainly on STD/CTD equipment, mechanical bathythermographs, and laboratory salinometers.

Underwater Research Areas (17; see also URA map). Considerable study takes place in the coastal waters adjoining the Scripps campus. These waters include special reserves, some of which have been set aside specifically for research.

Scripps Shoreline Reserve — The oldest extant reserve in the underwater research areas off the Scripps campus is the Scripps Shoreline Re-

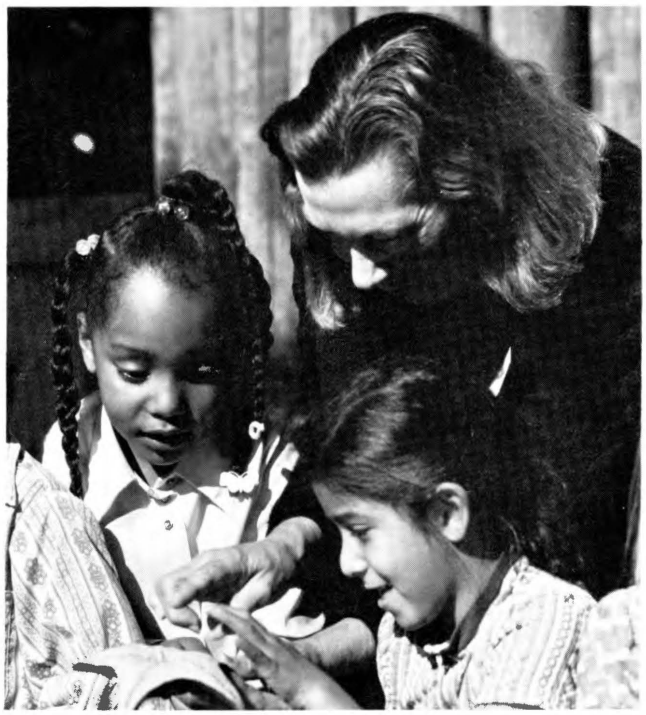




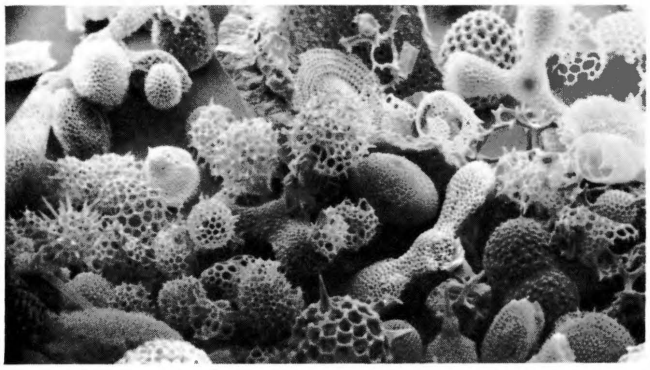
Dr. Charles J. Merdinger, deputy director, at left, greets scientists from Soviet Union who in August toured Scripps laboratories and discussed marine ecological problems with faculty members and students. Visitors were, second from left, group leader Dr. V. N. Maximov, Department of Biology, Moscow State University; next, Dr. Ivan B. Tokin, director, Murmansk Marine Biological Institute; and at right, Dr. Gennadii G. Polikarpov, a specialist affiliated with the Institute of Biology of the South Seas, Sevastopol. Russian scientists were in this country under terms of a cooperative agreement signed in 1972 by President Nixon and USSR President Nikolai V. Podgorny by which scientists of the two countries are working on, and exchanging information about, ocean pollution problems, weather research, earthquake prediction, air pollution control, urban problems, arctic ecology, and other subjects.

Heidi J. Hahn, assistant education coordinator for Vaughan Aquarium-Museum, describes large clam shell to Unni Ellisen, of Norway, at left, and Helene Franklert-Barcle, of Sweden, during visit of more than 100 Scandinavian young people to campus.

Photo courtesy of San Diego Evening Tribune



Vaughan Aquarium-Museum docent shows elementary-school students a starfish's mouth, located on its underside. Animal is one of many displayed in new tide-pool exhibit, which opened in 1975.



Foraminifera (large objects) and radiolaria (coarse-meshed objects) from the Pacific Ocean floor photographed through scanning electron microscope with magnification of 75X for 3¾" x 2⅞" print of full frame.

Dr. Stanley L. Kling

serve, which consists of a 100-acre tract of seashore and ocean that extends to a line 300 m seaward of the lowest low tide. All marine plants and invertebrates are protected for research, and the area has been used extensively for studies by Scripps staff and graduate students and for instructional purposes by outside institutions as well as by UC San Diego.

Scripps Submerged Land Area — The University of California leases from the City of San Diego approximately 2.6 km^2 of submerged land that extends seaward and to the north of Scripps. Included within this area is a Navy-designated, restricted area, currently unmarked by buoys, which is reserved for the installation of oceanographic instruments by the Navy and Scripps.

Ecological Reserve — The 580-acre San Diego-La Jolla Ecological Reserve extends southward from the Submerged Land Area to Goldfish Point in La Jolla. The zone was established primarily for conservation, and is protected from any collecting. A group of trained volunteers from Scripps's aquarium-museum acts as guides during low-tide periods, when tide-pool life is in jeopardy. The reserve, established in 1972, has shown measurable return to its original pristine conditions. The Ecological Reserve and the areas west and north of the leased Submerged Land Area are included in the 4,600-acre San Diego-La Jolla Underwater Park.

Special Collections

Deep Sea Drilling Project Core Repository (18). Scripps houses the West Coast Repository for cores collected by DSDP. The DSDP is part of the National Science Foundation's (NSF) Ocean Sediment Coring Program. Cores stored at this repository come from the Pacific and Indian oceans. (Cores from the Atlantic, Mediterranean, Antarctic, and Caribbean regions are stored at the East Coast Repository at Lamont-Doherty Geological Observatory of Columbia University.) Samples from these cores are made available to qualified researchers throughout the world under policies established by NSF.

Geological Samples (3-basement). This collection has more than 4,000 deep-sea sediment cores, which are kept under refrigeration. It also contains rocks and manganese nodules collected mainly from the Pacific and Indian oceans. These materials are available for study by scientific investigators; students may have access to the cores.

Geologic Data Center (5). Geologic data collected by Scripps vessels are cataloged and stored at this location. Index charts have been made for several hundred thousand nautical miles of expedition tracks through all sectors of the Pacific Ocean and part of the Arctic Ocean. Also available are overlays of the bathymetry, magnetic anomalies, and seismic reflection profiles and refraction stations. The original seismic reflection profiles are recorded on microfilm. Colored charts of the bathymetry and sediments of the North Pacific may be ordered from the Institute of Marine Resources. The originals are at a 1:3,000,000 scale and are kept at the Geologic Data Center, where they are displayed and continually updated.

Marine Invertebrates (Zooplankton Collection. 7, and 16 km southeast of Scripps). During 1974-75, all of the collection's routine one-meter net samples from the continuing CalCOFI program were transferred to an off-campus university laboratory at the Southwest Regional Calibration Center in San Diego. All of the other zooplankton

specimens will remain on the Scripps campus. In the entire collection there are more than 61,000 samples; of these more than 24,000 are epipelagic samples from special expeditions and individual research programs and some 1,500 are Isaacs-Kidd mid-water trawl samples. Total yearly increases to the collection will average between 1,000 and 1,500 samples. Almost all samples are supplemented with meteorological and physical/chemical data.

Marine Vertebrates (Fish Collection. 7). More than 2,500 cataloged species of marine fishes and in excess of one million specimens are in this collection. Added in Fiscal 1975 were 525 collections of bathypelagic and shore fishes. This year also saw the acquisition of a coelacanth (*Latimeria chalumnae)* from the Comoro Islands, off the northeast coast of Africa.

Oceanographic Data Archives. Tide-gauge records, taken daily since 1925 at the Scripps Pier, are held at the Scripps Diving Locker for two months and then mailed to: Director, National Ocean Survey (NOAA), Attn. C3313, Rockville, Maryland 20852.

Temperature and salinity records from southern California shore stations, taken daily since 1916, with data from more than 20,000 hydrographic casts, are managed by the Data Collection and Processing Group (DCPG) of the Marine Life Research Group. Summaries of the shore-station data, issued annually, are available upon request to: Technical Publications, Director's Office, Scripps Institution of Oceanography, A-010, La Jolla, California 92093.

Records from more than 500,000 Pacific- and Indian-ocean bathythermograph observations, taken since 1941, are now available through the National Oceanographic Data Center, Washington, D.C.

PUBLICATIONS

Introduction

The publications of the Scripps Institution of Oceanography are the end product of the faculty and staff's research. These publications are usually highly technical, ranging from long genus revisions to short internal data reports. Scripps publications are generally distributed by subscription, exchange or government contracts.

Below are listed the various Scripps Institution of Oceanography publications for 1974-1975, including information on their availability.

Bulletin

The *Bulletin of the Scripps Institution of Oceanography* contains lengthy, in-depth scientific papers by the faculty and staff. The bulletin is the only SIO publication available by subscription. For information about subscriptions and a list of those numbers available please write: University of California Press, 2223 Fulton Street, Berkeley, California 94720.

Note: There were no volumes of the bulletin published in 1974-75; however, three volumes are planned for 1975-76.

CalCOFI Atlas Series

The *California Cooperative Oceanic Fisheries Investigations* (CalCOFI) *Atlas Series* contains data on the hydrography and plankton of the region of the California Current. The series, started in 1963, reflects the work of the CalCOFI program, sponsored by the State of California under the direction of the state's Marine Research Committee, of which Scripps is one of five cooperating agencies.

The atlases are distributed at no charge to research institutions, university libraries, and qualified research scientists active in oceanographic fields relating to the CalCOFI program. Editions are limited to 650 copies.

Those interested, please write to: Dr. Abraham Fleminger, Scripps Institution of Oceanography, A-001, La Jolla, California 92093.

No. 1 *CalCOFI atlas of 10-meter temperatures and salinities, 1949-59. 1963.*

No. 2 *FLEMINGER, A. Distributional atlas of calanoid copepods in the California Current region, Part I. 1964.*

No. 3 *ALVARINO, A. Distributional atlas of Chaetognatha in the California Current region. 1965.*

No. 4 *WYLLIE, J. G. Geostrophic flow of the California Current at the surface and at 200 meters. 1966.*

No. 5 *BRINTON, E. Distributional atlas of Euphausiacea (Crustacea) in the California Current region, Part I. 1967.*

No. 6 *MCGOWAN, J. A. Distributional atlas of pelagic molluscs in the California Current region. 1967.*

No. 7 *FLEMINGER, A. Distributional atlas of calanoid copepods in the California Current region, Part II. 1967.*

No. 8 *BERNER, L. D. Distributional atlas of Thaliacea in the California Current region. 1967.*

No. 9 *KRAMER, D. and E. H. AHLSTROM. Distributional atlas of fish larvae in the California Current region: Northern Anchovy,* Engraulis mordax *(Girard), 1951-1965. 1968.*

No. 10 *ISAACS, J. D., A. FLEMINGER and J. K. MILLER. Distributional atlas of zooplankton biomass in the California Current region: Spring and Fall, 1955-59. 1969.*

No. 11 *AHLSTROM, E. H. Distributional atlas of fish larvae in the California Current region: jack mackerel,* Trachurus symmetricus *and Pacific hake,* Merluccius productus, *1951-66. 1969.*

No. 12 *KRAMER, D. Distributional atlas of fish eggs and larvae in the California Current region; Pacific sardine,* Sardinops caerulea *(Girard), 1951-66. 1970.*

No. 13 *SMITH, P. E. Distributional atlas of zooplankton volume in the California Current region, 1951-66. 1971.*

No. 14 *ISAACS, J. D., A. FLEMINGER and J. K. MILLER. Distributional atlas of zooplankton biomass in the California Current region: Winter 1955-59. 1971.*

No. 15 *WYLLIE, J. G. and R. J. LYNN. Distribution of temperature and salinity at 10-meters, 1960-69, and mean temperature, salinity and oxygen at 150-meters, 1950-68, in the California Current. 1971.*

No. 16 *CROWE, F. J. and R. A. SCHWARTZLOSE. Release and recovery records of drift bottles in the California Current region, 1955-71. 1972.*

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Contributions

This annual publication is a compilation of selected reprints authored by the Scripps faculty and staff. The *Scripps Institution of Oceanography Contributions* is available only on an exchange basis to other scientific, research, and educational institutions. For exchange information, please write: Gifts and Exchange Department, Library, University of California, San Diego, La Jolla, California 92093.

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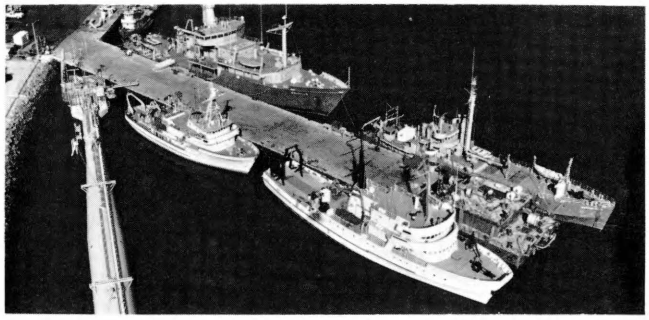
Representatives from the United States, Canada, Sweden, New Zealand, Australia, and France attended a five-day Expert Meeting on Carbon Dioxide Monitoring scheduled on campus by the United Nations World Meteorological Organization. Meeting marked first time that representatives of all the world's carbon dioxide-measuring laboratories had convened. Participants from Scripps were Dr. Robert B. Bacastow (not in picture); Arnold Bainbridge, second from left; and Dr. Charles D. Keeling, third from left, making a point during a discussion. At far end of table, at right, is Dr. C. S. Wong, a Scripps graduate who now heads up the Ocean Chemistry Division, Marine Sciences Directorate (Pacific Region), Department of the Environment, Victoria, Canada.



Research vessels at Nimitz Marine Facility.

San Diego Bay, as seen through "A" frame on fantail of R/V Melville.

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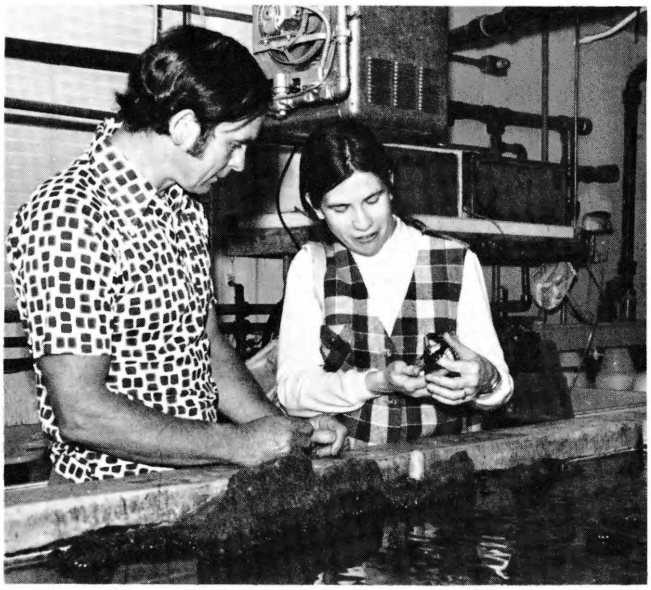
Research geophysicist Professor Victor Vacquier, at left; his wife, Mihoko; Dr. Mizuki Tsuchiya, associate research oceanographer, second from left, use model in Vaughan Aquarium-Museum to show visitors the two submarine canyons off institution's campus. Pointing to locations are Mayor Shun Hayama, of Fujisawa, Japan, center, which is near San Diego's sister city of Yokohama, and Mas Ohkubo, second from right, vice-president and manager of the San Diego Branch of Sumitomo Bank of California.

Among the scores of visitors to the institution during the year was Uri Tzon, at right, director of the park system of Israel, bidding farewell to Don Wilkie, director of the Vaughan Aquarium-Museum. Tzon and Wilkie conferred during the former's international tour of parks, aquariums, museums, and zoos to gather information for establishing an 8,000-acre park in Israel.

Reviewing agenda for annual visit of 75 oceanography students and instructors from Unidad de Ciencias Marinas (UCM), Universidad Autónoma de Baja California, in Ensenada, Mexico, to Scripps Institution are Mrs. William A. Nierenberg, co-chairman of arrangements for visit, and Adolfo Granados Guzmán, acting director of UCM. Annual exchange of visits between students from the school and UC San Diego began in 1961 as an activity coordinated by People-to-People, a women's international relations interest group of UCSD Oceanids, comprised of wives and women faculty members.



Mrs. Delia Laitin of Berkeley, California, granddaughter of the late Dr. Thomas Wayland Vaughan, who was director of Scripps Institution from 1923-1936, views a Baja California turtle during behind-the-scenes visit to Vaughan Aquarium-Museum with Don Wilkie, director. That facility was named for her grandfather.

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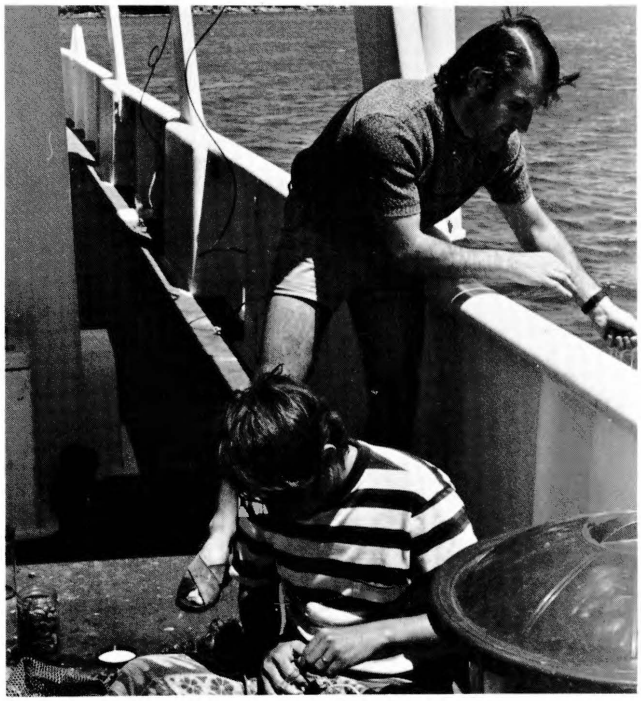
Timothy Morawetz, high school student from Peterborough, Ontario, Canada, measures concentration of ammonia excreted by fish in aquariums. Tim's studies were part of Vaughan Aquarium-Museum's summer Career Experience Exploratory Program.



On board the R/V Dolphin *in the Gulf of California, Dr. D. John Faulkner, standing, and graduate student Stephen J. Wratten prepare samples of sponges for research on antibiotic-producing fungus.*

Heidi Hahn

Laura Hubbs appears to be ducking that knife, but her smile contrasts her husband Carl's grim visage as he readies an attack on large cake he cut when friends and associates surprised the ichthyologist with a party on his 80th birthday.

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74-16 GLOCKHOFF, Carolyn and Phyllis B. HELMS. Description of cores from the central Pacific taken on STYX Expedition. May 1974. 20p.

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74-33 STIDD, C. K. Ship drift components: Means and standard deviations. NORPAX. November 1974. 56p. (oversized) AD A006 470.

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During their first trip to San Diego after being assigned to duty in Los Angeles, British Consul General Tom E. Aston and Mrs. Aston, at right, conferred with Director Nierenberg, visited laboratories, and toured Vaughan Aquarium-Museum.

STAFF *July 1, 1974 to June 30, 1975*

NAME	RESEARCH GROUP	FIELD
#Elbert H. Ahlstrom	Department SIO	Biological Oceanography
Roger N. Anderson	Marine Physical Laboratory	Geophysics
Victor C. Anderson	AP&IS/Marine Physical Laboratory/ Sea Grant College Program	Marine Physics
Gustaf Arrhenius	Geological Research Division	Oceanography
Robert S. Arthur	Ocean Research Division	Physical Oceanography
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Joseph A. Bastian	Neurobiology Unit	Neurobiology
Christopher Beaumont	Cecil H. & Ida Green Scholar	Geophysics
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+Dale W. Toetz	Institute of Marine Resources	Biology
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Shin-ichi Uye	Marine Life Research Group	Zooplankton Ecology
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Charles W. Van Atta	AMES/Sea Grant College Program	Geophysical Fluid Dynamics
David J. Vanderah	Ocean Research Division	Chemistry
William G. Van Dorn	Ocean Research Division/ Advanced Ocean Engineering Laboratory	Physical Oceanography
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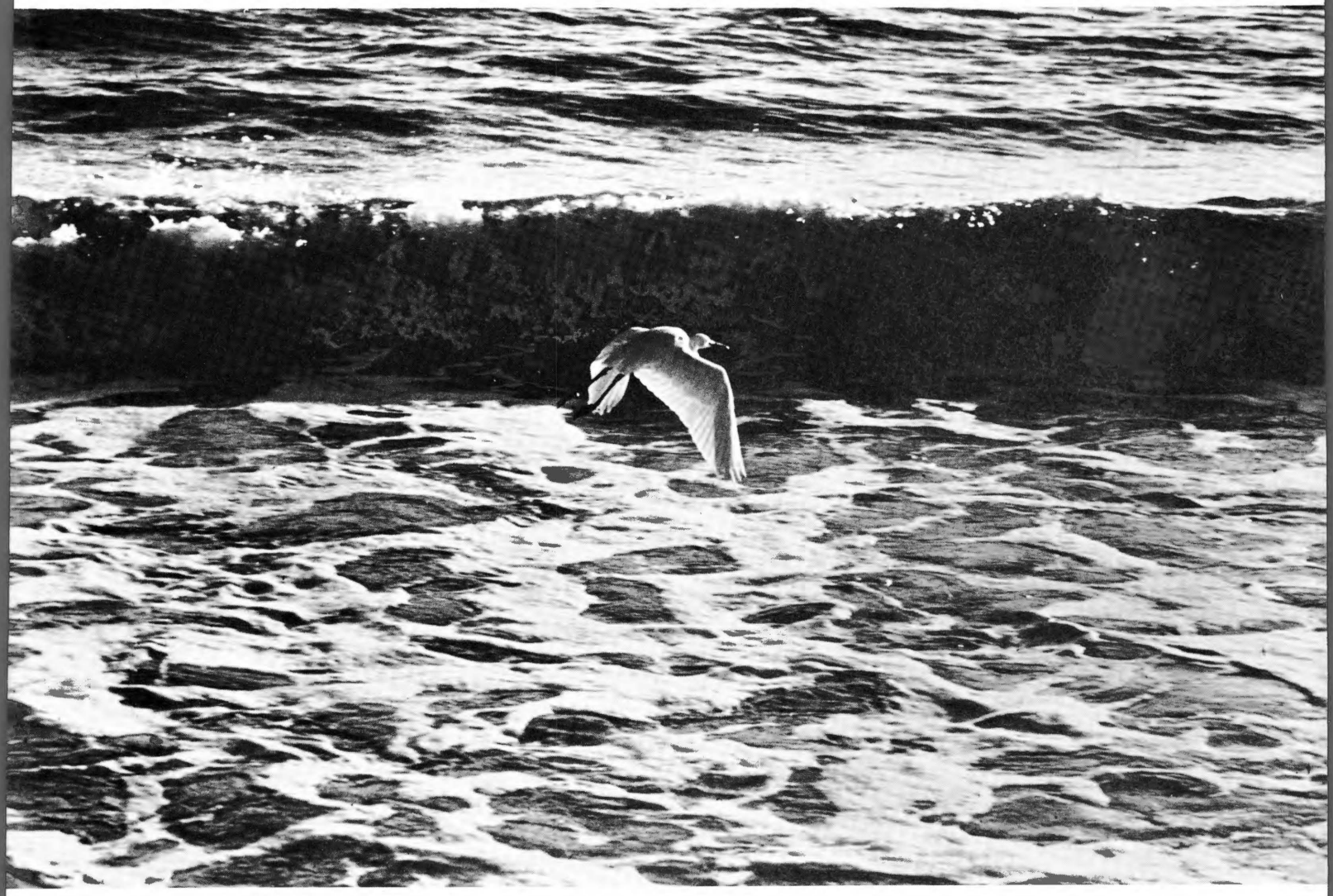

Jack Zane

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Seth Sprague Foundation
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Texaco, Incorporated
U. S. Steel
Union Oil Company
University Research Foundation
Van Camp
Westinghouse Electric Corporation

Appendix C
MAJOR AWARDS AND HONORS

Dr. Gustaf Arrhenius
  Elected a Foreign Member of the Swedish Royal Academy of Sciences.
Dr. Jeffrey L. Bada
  Received a Sloan Research Fellowship from the Alfred P. Sloan Foundation. Honored by the UC San Diego Chancellor's Club for his research. Selected an Outstanding Young Man of San Diego by the San Diego Jaycees. Given a Headliner Award in archaeology by the San Diego Press Club.
Sir Edward C. Bullard
  Awarded the William Bowie Medal of the American Geophysical Union.
Dr. Paul K. Dayton
  Received the Mercer Award from the Ecological Society of America.
Dr. Carl L. Hubbs
  Honored on his 80th birthday by the dedication of an issue of *Copeia*, the journal of the American Society of Ichthyologists and Herpetologists. Given a Headliner Award in science by the San Diego Press Club. Recognized by the establishment of a Carl L. Hubbs Sea World Fellowship in Marine Biology at Scripps.
Dr. Devendra Lal
  Elected a Foreign Associate of the National Academy of Sciences.
Dr. Henry W. Menard
  Elected a Fellow of the American Academy of Arts and Sciences.
Dr. Walter H. Munk
  Received Honorary Doctor of Philosophy, University of Bergen, Bergen, Norway.
Joseph L. Reid
  Elected a Fellow of the American Geophysical Union.
Larry E. Ritchie, graduate student
  Received the Best Paper Award from the Western Society of Naturalists.
Dr. Per F. Scholander
  Elected a Foreign Member of the Swedish Royal Academy of Sciences.
Dr. Claude E. ZoBell
  Received the Environmental Conservation Distinguished Service Award of the American Institute of Mining, Metallurgical, and Petroleum Engineers.

In animated discussion with Deputy Director Charles J. Merdinger, right, about the "good, old days" at Scripps is Dr. Norris W. Rakestraw, professor of chemistry emeritus, whose 80th birthday was celebrated on campus by friends and former colleagues. Dr. Rakestraw, who came from his Morongo Valley, California, home for the occasion, served on the faculty from 1946 until he attained emeritus status in 1965.

RESEARCH VESSELS OF SCRIPPS INSTITUTION OF OCEANOGRAPHY

	Alexander Agassiz	Alpha Helix	Dolphin	Melville	Oconostota	Ellen B. Scripps	Thomas Washington	FLIP	ORB
Type:	light freight	oceanographic research (biological)	oceanographic research	oceanographic research	tug	offshore supply	oceanographic research	floating instrument platform	oceanographic research buoy
Hull:	steel	steel	aluminum	steel	steel	steel	steel	steel	steel
Year Built:	1944	1965-1966	1968	1969	1944	1964-1965	1965	1962	1968
Year acquired by SIO:	1961	1966	1973	1969	1962	1965	1965	1962	1968
From whom acquired:	State Educational Agency for Surplus Property	National Science Foundation	Robert O. Peterson	U.S. Navy	U.S. Navy	Dantzler Boat and Barge Co.	U.S. Navy	Gunderson Bros. Shipbuilding Co.	U.S. Navy
Owner:	University of California	University of California	University of California	U.S. Navy	U.S. Navy	University of California	U.S. Navy	U.S. Navy	U.S. Navy
Length:	180′	133′	96′	245′	102′	95′	209′	355′	69′
Beam:	32′	31′	22′	46′	25′	24′	40′	20′/12′	45′
Draft:	10′	10′5½″	8′6″	15′	10′	6′	14′	10′/300′	fwd. 4′10½″ aft 5′4½″
Displacement: Tons (full):	869	512	96.09	1,915	206	115	1,362	2,100 (vertical)	299.5
Maximum speed:	11	10.5	14	12	11	9	12.5	varies[-1]	varies[-1]
Minimum speed:	0-1	0-3	0-3	0-1	0-1	1	0-1	varies[-1]	varies[-1]
Range (miles):	5,940	6,200	2,000	9,840	4,500	6,480	8,700	varies[-1]	varies[-1]
Endurance (days):	22	30	7	41	16	30	29	varies[-1]	30
Crew:	18	12	5	25	8	5	25	5	5
Scientific party:	13	12	8	25	6	8	17	11	12

[-1]Depends on towing vessel

1974-75 TOTAL DAYS AT SEA: 1,467
1974-75 NAUTICAL MILES STEAMED: 163,237

Appendix E

DOCTOR OF PHILOSOPHY DEGREES AWARDED IN 1974-75 WITH TITLES OF DISSERTATIONS

Earth Sciences

Terrance G. Barker, "Static Strain in a Non-Uniform Solid: With Applications to California."

David A. Clague, "The Hawaiian-Emperor Seamount Chain: Its Origin, Petrology, and Implications for Plate Tectonics."

Allan F. Divis, "The Geology and Geochemistry of the Sierra Madre Mountains, Wyoming."

Richard D. Jarrard, "Pacific Plate Motions."

Douglas W. Oldenburg, "Geophysical Modeling of Oceanic Ridges."

Harald S. Poelchau, "Holocene Silicoflagellates of the North Pacific: Their Distribution and Use for Paleotemperature Determination."

Brian E. Tucker, "Source Mechanisms of Aftershocks of the 1971 San Fernando, California Earthquake."

Marine Biology

Edward B. Brothers, "The Comparative Ecology and Behavior of Three Sympatric California Gobies."

Bonnie J. Davis, "Temperature Adaptations, and Distributions, in the Fish Genus *Gibbonsia.*"

Gary H. Dobbs, III, "Aglomerularism in Antarctic Teleost Fishes."

John G. Duman, "The Role of Macromolecular Antifreeze Solutes in Freezing Resistance of Cold Water Fishes."

Thomas H. Ermak, "Cell Proliferation in the Ascidian *Styela clava:* An Autoradiographic and Electron Microscopic Investigation Emphasizing Cell Renewal in the Digestive Tract of This and Fourteen Other Species of Ascidians."

Francis J. Rokop, "Breeding Patterns in the Deep Sea."

Mia J. Tegner, "Sea Urchin Sperm-Egg Interactions and the Block Against Polyspermy: A Scanning Electron Microscope and Experimental Study."

Oceanography

Raymond J. Andersen, "Chemical Studies of Primitive Marine Organisms: Porifera and Bacteria."

Kenneth W. Bruland, "Pb-210 Geochronology in the Coastal Marine Environment."

John E. Cromwell, "Processes, Sediments, and History of Laguna Superior, Oaxaca, Mexico."

Thomas F. Dana, "Ecological Aspects of Hermatypic Coral Distributions in Three Different Environments."

John R. Dingler, "Wave-Formed Ripples in Nearshore Sands."

Jimmie L. Greenslate, "Manganese-Biota Associations in Northeastern Equatorial Pacific Sediments."

Robert T. Guza, "Excitation of Edge Waves and Their Role in the Formation of Beach Cusps."

Robert F. Hartwick, "Orientation Behavior in Beachhoppers of the Genus *Orchestoidea:* Capacities and Strategies."

William D. Ivers, "The Deep Circulation in the Northern North Atlantic, with Especial Reference to the Labrador Sea."

Thomas C. Johnson, "The Dissolution of Siliceous Microfossils in Deep-Sea Sediments."

Peter A. Jumars, "Dispersion Patterns and Species Diversity of Macrobenthos in Two Bathyal Communities."

Kim D. Klitgord, "Near-Bottom Geophysical Surveys and their Implications on the Crustal Generation Process, Sea-Floor Spreading History of the Pacific and the Geomagnetic Time Scale: 0 to 6 M.y.b.p."

Peter F. Lonsdale, "Abyssal Geomorphology of a Depositional Environment at the Exit of the Samoan Passage."

Philip S. Low, "Molecular Mechanisms of Enzyme Adaptation to Temperature and Pressure."

Jon S. Mynderse, "Halogenated Monoterpenes from *Plocamium cartilagineum* Dixon and *Plocamium violaceum* Farlow."

Mary J. Perry, "Dynamics of Phosphate Utilization by Marine Phytoplankton in Chemostat Cultures and in Oligotrophic Waters of the Central North Pacific Ocean."

Robert Pinkel, "Observations of Internal Waves in the Upper Ocean."
Roy A. Schroeder, "Kinetics, Mechanism and Geochemical Applications of Amino Acid Racemization of Various Fossils."
Gary B. Smith, "Some Effects of Sewage Discharge to the Marine Environment."
Martha O. Stallard, "Chemical Constituents of the Sea Hare *Aplysia californica*."
Gordon O. Williams, "Microstructure and Internal Wave Measurements from a Midwater Float."

MASTER OF SCIENCE DEGREES AWARDED IN 1974-75

Earth Sciences
Paul A. Spudich

Marine Biology
Diana J. Gabaldon
F. Sophia Hu

Oceanography
Michael D. Applequist
Jeffrey T. Dillingham
Craig L. Etka
Robert E. Fricks
Lloyd L. Green
Steven E. Moran
Ronald L. Oda
Richard W. Robinson
Gregory W. Withee

Appendix F

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

REGENTS EX OFFICIO
Edmund G. Brown, Jr.
Governor of California and President of The Regents
Mervyn M. Dymally
Lieutenant Governor of California
Leo T. McCarthy
Speaker of the Assembly
Wilson Riles
State Superintendent of Public Instruction
Edward A. Morris
President of the Alumni Association of the University of California
James Collins
Vice President of the Alumni Association of the University of California
David S. Saxon
President of the University

APPOINTED REGENTS
Edward W. Carter
Mrs. Randolph A. Hearst
Norton Simon
William E. Forbes
William M. Roth
Mrs. Edward H. Heller
Chairman of the Board
Frederick G. Dutton
William K. Coblentz
DeWitt A. Higgs
Glenn Campbell
William French Smith
Vice Chairman of the Board
Robert O. Reynolds
Joseph A. Moore, Jr.
Dean A. Watkins
John H. Lawrence
William A. Wilson
Carol Lynn Mock

PRINCIPAL OFFICERS OF THE REGENTS
Donald L. Reidhaar
General Counsel
Owsley B. Hammond
Treasurer
Marjorie J. Woolman
Secretary

SYSTEMWIDE ADMINISTRATION
David S. Saxon
President of the University
Chester O. McCorkle, Jr.
Vice President of the University
Donald C. Swain
Academic Vice President
Archie Kleingartner
Vice President–Academic and Staff Personnel Relations
James B. Kendrick, Jr.
Vice President–Agricultural Sciences
John A. Perkins
Vice President–Business and Finance
Robert L. Johnson
Vice President–University and Student Relations
Angus E. Taylor
University Provost
Lowell J. Paige
Special Assistant to the President for Governmental Relations
Dorothy E. Everett
Assistant President–Coordination and Review
Beverly Ruth Liss
Assistant President–Campus and Internal Relations

OFFICERS EMERITI
Clark Kerr
President of the University, Emeritus
Charles J. Hitch
President of the University, Emeritus
Claude B. Hutchison
Vice President of the University, Emeritus, and Dean of the College of Agriculture, Emeritus
Harry R. Wellman
Vice President of the University, Emeritus
Robert M. Underhill
Vice President, Emeritus, and Secretary and Treasurer of The Regents, Emeritus
Thomas J. Cunningham
General Counsel, Emeritus

CHANCELLORS
Albert H. Bowker
Chancellor at Berkeley
James H. Meyer
Chancellor at Davis
Daniel G. Aldrich, Jr.
Chancellor at Irvine
Charles E. Young
Chancellor at Los Angeles
Ivan Hinderaker
Chancellor at Riverside
William D. McElroy
Chancellor at San Diego
Francis A. Sooy
Chancellor at San Francisco
Vernon I. Cheadle
Chancellor at Santa Barbara
Mark N. Christensen
Chancellor at Santa Cruz

Appendix G

CURRENT FUNDS EXPENDITURES BY MAJOR UNITS AND FUNCTIONS BY FUND SOURCE 1974-1975

		Institutes		
	Scripps Institution of Oceanography	Geophysics and Planetary Physics	Marine Resources	Total
STATE OF CALIFORNIA				
General	$ 4,306,124	$ 164,989	$ 285,824	$ 4,756,937
Other	150,563	—	135,339	285,902
Total State of California	4,456,687	164,989	421,163	5,042,839
STUDENT TUITION & FEES	48,219	726	84,817	133,762
UNITED STATES OF AMERICA				
Grants—				
Department of Defense—Air Force	—	37,301	—	37,301
Department of Health, Education and Welfare	16,778	1,277	915	18,970
National Aeronautics and Space Administration	85,165	74,684	—	159,849
National Institutes of Health	243,802	500	—	244,302
National Science Foundation	6,195,087	456,220	341,315	6,992,622
Other	106,761	47,703	693,663	848,127
Total Grants	6,647,593	617,685	1,035,893	8,301,171
Contracts—				
Atomic Energy Commission	307,312	81,360	352,895	741,567
Department of Defense				
Air Force	478,173	—	—	478,173
Army	33,289	—	—	33,289
Navy	6,116,030	280,117	—	6,396,147
National Aeronautics and Space Administration	—	4,534	—	4,534
National Science Foundation	11,581,964	—	—	11,581,964
Other	243,763	—	—	243,763
Total Contracts	18,746,166	366,011	352,895	19,465,072
Total United States of America	25,408,124	983,696	1,388,788	27,780,608
ENDOWMENT FUNDS	578,455	43,230	158,228	779,913
GIFTS AND PRIVATE GRANTS	824,685	62,365	118,431	1,005,481
SALES AND SERVICES	117,687	13,149	13,314	144,150
OTHER SOURCES	(31,869)	—	—	(31,869)
Total Current Funds Expenditures	$31,401,988	$1,268,155	$2,184,741	$34,854,884

UCSD
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