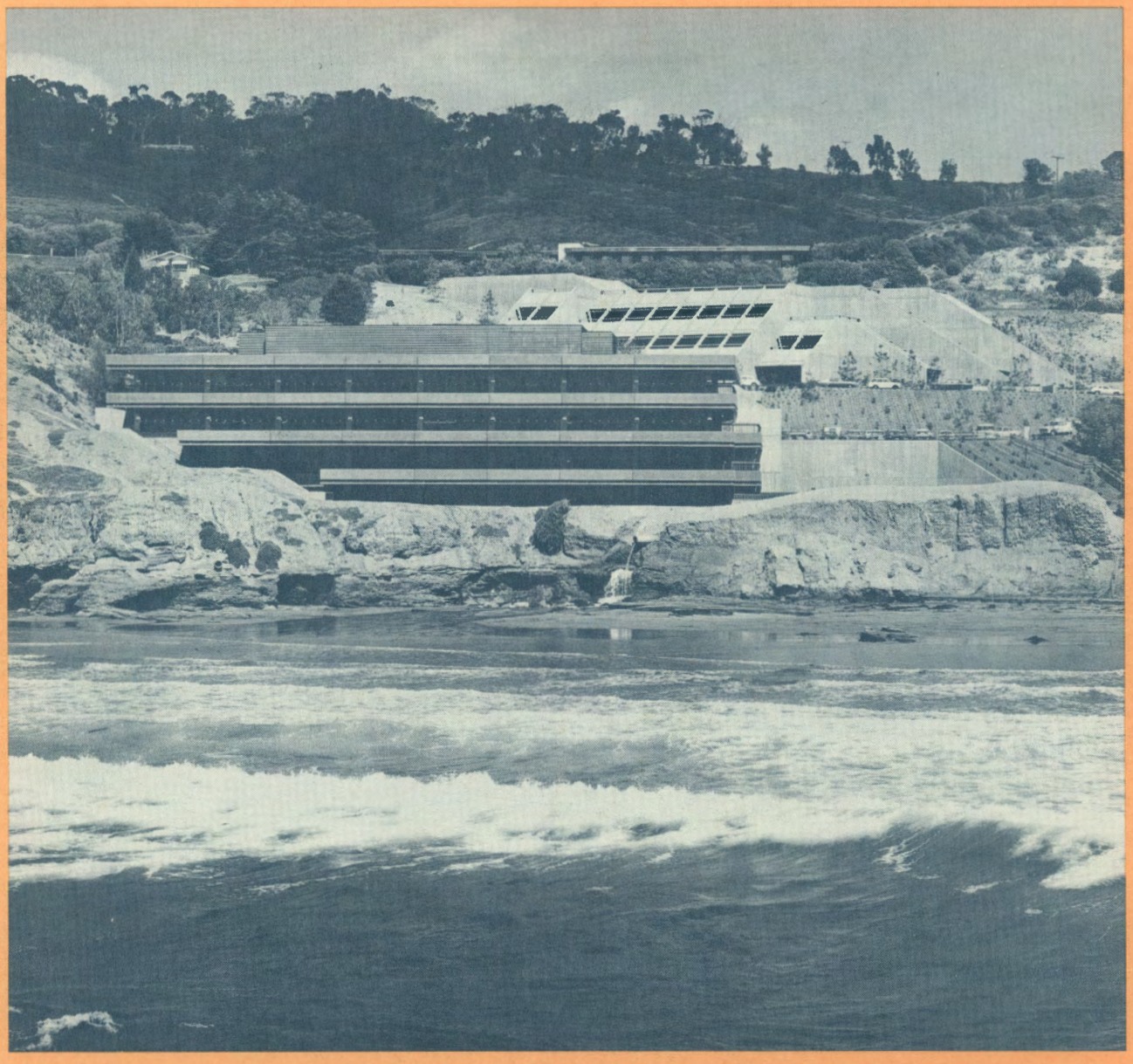

Scripps Institution of Oceanography

UNIVERSITY OF CALIFORNIA, SAN DIEGO

1977

SCRIPPS INSTITUTION OF OCEANOGRAPHY

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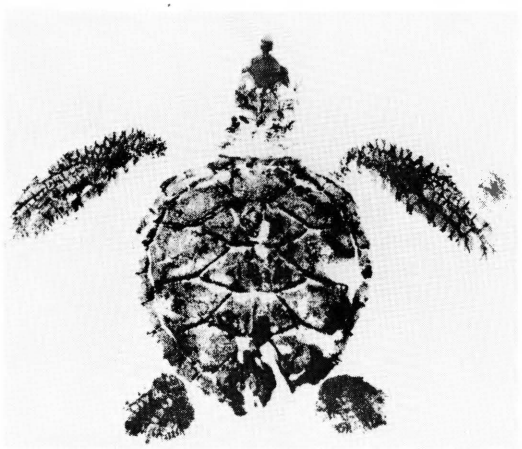
Cover photo: Marine Biology Building (foreground) and Scripps Library.



Animal print of 13-cm green turtle, Chelonia mydas, *found in Pacific coastal waters from San Diego to southern Chile. To create this impression, porous paper was carefully pressed against the inked turtle's body. This technique, a Japanese art called gyotaku, is commonly referred to as fish printing.*
Heidi J. Hahn

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DEDICATION

Smiles and a handclasp between Dr. Roger R. Revelle (left), then director of Scripps, and Jeff Frautschy indicate the last-minute arrival in San Diego of 10,668 m of brand new, tapered wire ready to be wound on to a drum in the hold of R/V Spencer E. Baird *the night before she departed on the institution's second major expedition, Capricorn (1952-53). This was the first cable longer than 6,098 m that Scripps had used on an expedition. Capricorn was led by Dr. Revelle as chief scientist; he also headed Operation Mid-Pac two years earlier. Director emeritus of Scripps, Dr. Revelle presently holds joint professorships at UC San Diego and Harvard University, Cambridge, Massachusetts.*

John B. MacFall

Transplant a midwestern geologist to the West Coast, expose him to the Pacific Ocean for 35 years, and whom do you get? Answer: a quiet, unassuming, soft-spoken gentleman, Jeffery D. Frautschy by name, known to hundreds of friends and business associates as Jeff.

How he got to San Diego is a story in itself. One day in 1942, fresh from the University of Minnesota (UM) with a bachelor's degree in geology and a year of graduate study, Jeff received a long-distance telephone call from one of the UM professors under whom he had studied and who by then had become affiliated with the University of California Division of War Research (UCDWR), in San Diego. The professor offered Jeff a job, but couldn't describe the nature of the work because of wartime security. He expressed his belief that Jeff could handle the assignment, however, and then, somewhat as an afterthought, asked whether he ever got seasick. Jeff replied he never had, but failed to add that neither had he ever been within a thousand miles of the ocean. He did accept the offer, nevertheless.

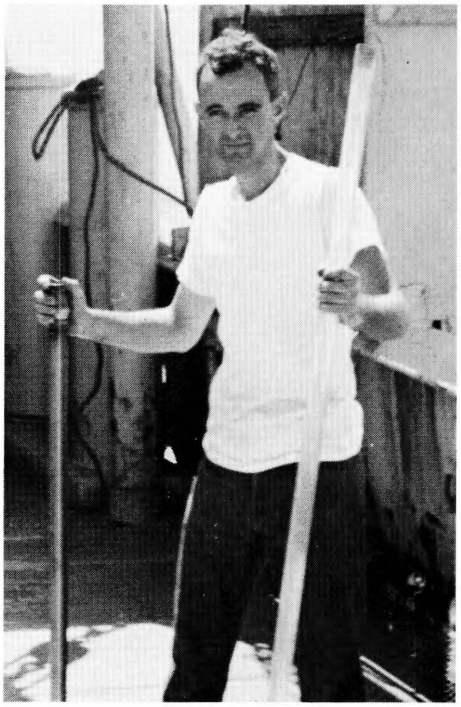
The day after his arrival in San Diego, Jeff put to sea for UCDWR on the Navy's USS *Jasper* (PYC-13), later to become Scripps's R/V *Stranger,* and didn't get seasick. Since that initial cruise, he has spent many days aboard research vessels for UCDWR and Scripps Institution, developing and installing equipment and instrumentation, checking gear, taking sediment cores, and "shooting the breeze." With the war over, and after a year of graduate work at Scripps, Jeff interrupted his university affiliation with two years at the U.S. Geological Survey and in graduate study at the University of Southern California from 1947 to 1949, when he joined Scripps. He has been assistant director since 1958, and in 1975 was given the additional duties of associate director of the university's Scripps-based Institute of Marine Resources, with responsibilities for coastal resources and Sea Grant.

Over the years, Jeff's interests have been far ranging, particularly in the area of research engineering. He's involved in, and become knowledgeable about, the outfitting and operation of research vessels, the administration and operation of research support facilities ashore, oceanographic instrumentation, marine geology, shore processes, geophysics, water quality, and coastal zone management. Typical of his engineering expertise was his development of a more satisfactory wire rope. This was a coreless, three-strand rope that lasted much longer than the seven-strand wire that incorporated a central core (aircraft cord) and had been used earlier. He also helped develop equipment for reading and digitizing bathythermograph data.

As assistant director, Jeff coordinated Scripps's scientific participation in the International Geophysical Year program of the late 1950s, and he has acted as a campus trouble-shooter *par excellence.* During the institution's building boom in the 1950s and 1960s, it was Jeff who knew the location of utility connections around the campus, and for many years he has kept track of the institution's structures, its ships, and its people.

Finally, in accordance with the mandate that the university should also serve the public, Jeff's interest in matters ecological has resulted in his spending untold hours of dedicated membership on both the San Diego and State Coastal Conservation commissions since their establishment in 1972, and to years of prior service on the San Diego Regional Water Quality Control Board. In related fields, he is a member of the Coordinating Board of UC's Water Resources Center and has served the San Diego Unified School District as a member of its Marine Technology Advisory Committee and the San Diego Chamber of Commerce on its Oceanographic Committee and Water Pollution Board.

All in all, quite a record of achievement for a chap who hadn't been within a thousand miles of the ocean until he came west in 1942.



Aboard R/V Horizon *during Scripps's first major expedition, Operation Mid-Pac (Mid-Pacific, 1950), a young research geologist named Jeffery D. (Jeff) Frautschy holds sediment core sample in his left hand, the core barrel in his right. Jeff was named assistant director of Scripps in 1958.*

Edward S. Barr

INTRODUCTION

We begin with our sad duty to report the passing of Milton N. Bramlette and E. W. "Bill" Fager. Professor Bramlette had been retired for many years and was in ill health for the last few. Therefore, he was not well known to younger members of the staff. He did many great things in geology, and has had a profound influence on the development of marine geology at the institution.

Bill Fager died at a much younger age than Professor Bramlette, after a long and difficult illness. His was a career that was cut short in prime, and we can only guess at the important things he would have accomplished had he been permitted to continue his work in ecology.

On a happier side, this report carries the longest list of individual awards received in any one year by faculty, staff, and students. Happier still was the completion and occupancy of the new Marine Biology Building and the new Scripps Library. Despite the dislocation involved, we really enjoy the new additions to the campus. The $9.5 million expended for these buildings plus the $3.33 million for the new research ship, *New Horizon*, will probably be the largest single expenditure of state funds in one year at the institution. Furthermore, we are looking ahead with some real possibility to the construction of a collections building and a physical oceanography building.

The regents have approved our request to have the new Scripps Library Building named after Carl Eckart. And thanks to the efforts of many volunteers, we have a beautiful reading room dedicated to Helen Raitt in the new library, and that was also approved by the regents.

For once I will make no effort to predict the immediate future except that (to mix a metaphor) it can only be up. The uncertainties revolve about the new NOAA (National Oceanic and Atmospheric Administration), the new NACOA (National Advisory Committee on Oceans and Atmosphere), and the National Science Foundation's attitude toward the future of the Deep Sea Drilling Project and the continuation of the International Decade of Ocean Exploration.

Other concerns are related to the 200-mile fishing limit and the general problems of research in that region and on the high seas. It looks as though we and our sister institutions will have to employ bilateral negotiations even more than in the past.

Carl and Laura Hubbs (right) stand beside Director Nierenberg, who spoke at dedication ceremonies of the Hubbs-Sea World Research Institute, San Diego, in May. On the easel is a plaque of Honduras mahogany, whose cameos of the Hubbses are carved in ash. Wood sculptor Ralph Patterson included carvings of nine significant marine genera and species that Dr. and Mrs. Hubbs have investigated in their life-long research. Starting from the upper right, clockwise, they are* Mesopolodon carlhubbsi*, beaked whale; a flatfish, a bull Guadalupe fur seal, a California sea otter, a northern elephant seal, a desert pup fish, a California gray whale, and a lamprey.

Photo courtesy of Sea World

William A. Nierenberg

William A. Nierenberg, Director
Scripps Institution of Oceanography

MAJOR BUILDINGS COMPLETED

For the first time in the history of the institution, two, new, modern structures were completed and occupied during the fiscal year as plans progressed for the dedication on September 21, 1977, of the $6.6 million Marine Biology Building and the $3 million Scripps Library Building, named for the late Dr. Carl H. Eckart. Dr. Eckart had served as director of Scripps from 1948 to 1950, as the first director of the institution's Marine Physical Laboratory, and as vice-chancellor for academic affairs in UC San Diego's early days.

At year's end, Dr. Frank Press, director of the Office of Science and Technology Policy in the Executive Office of the President–in effect, President Carter's science and technology advisor–had accepted an invitation to be principal speaker at the dedication.

The new buildings are the first major structures to be erected on campus since the Physiological Research Laboratory was completed in June 1965. They are also the first state-funded buildings constructed at the institution since completion of Sverdrup Hall in 1960. Brief descriptions of both buildings follow.

Marine Biology Building

Ground was broken for the Marine Biology Building on March 20, 1974. The four-level, reinforced-concrete structure contains 6,500 gross m^2 of space (or 3,600 assignable m^2) and incorporates unique culture facilities that simulate light and temperature conditions in all parts of the ocean.

Microorganisms and marine plants are grown and studied in these controlled environment systems; other laboratories provide research in fish behavior, developmental biology, biochemistry, photobiology, and other marine-related disciplines.

The building houses a large, multi-purpose, experimental aquarium; three, small, aquarium rooms supplied with ambient and chilled seawater; and analytical equipment, including an electron microscope with scanning and X-ray, energy-dispersive, ultramicroanalytical capabilities.

Seawater and other laboratory utilities are distributed throughout the air-conditioned structure from a central core that will facilitate future adaptation to specialized requirements of new or changing scientific demands.

Joined to the east side of the building at the fourth, or top, level is a conference room seating 90 persons.

With respect to energy-saving features, the building has a "dead band" system whereby heating and cooling equipment does not react within a range of 20-25°C, except in special, controlled, research areas. The earth adjacent to the first-and-second-floor levels helps moderate temperature changes and thus reduces energy requirements.

The building permits better coordination and interaction between scientists and students and a more efficient use of laboratory facilities formerly scattered throughout the institution.

Members of the biology building advisory committee included Dr. Andrew A. Benson, chairman; James L. Faughn, Jeffery D. Frautschy, Dr. Francis T. Haxo, George L. Matson, Donald L. McCarty, Dr. Michael M. Mullin, and Anton L. Witte.

The La Jolla firm of Liebhardt, Weston & Associates, A.I.A., served as architects for the building; general contractor was William Simpson Construction Company, San Diego.

Eckart Building of Scripps Library

Ground was broken for the Eckart Building of Scripps Library on July 16, 1975. The building contains 4,100 gross m^2 space, of which total 3,000 m^2 are assignable.

The three-story, reinforced, prestressed-concrete structure can accommodate more than 150,000 volumes. As of June 30, 1977, the building housed 116,080 bound volumes, 27,562 maps and charts, 20,611 reprints, 27,387 documents, reports, and translations, and 4,648 pieces of microcopy.

The new building, which replaces a structure built in 1916 that was scheduled to be razed early in the 1977-78 fiscal year, accommodates 150 readers in a variety of individual and group study areas.

Data-processing computer terminals enable scientists to tap worldwide computerized information sources and services through the use of telephone/ typewriter communications systems. One terminal permits the library to participate in a nationwide computerized, shared, cataloging network that included 750 libraries and is operated by the Ohio College Library Center, Columbus.

Other features include a periodical reading room and special sections for archives, rare books, and specialized reprints and collections; documents, reports, and translations; maps and charts; and microforms.

The earth on two sides of the building moderates temperature changes, and has a cooling effect in summer and a warming effect in winter. This energy-efficient design is expected to save about 48,000 kilowatts annually, and it has reduced equipment needs, over conventional designs, by 35 tons.

At ground-breaking time, members of the library advisory committee included Joseph L. Reid, chairman; Dr. D. John Faulkner, William J. Goff, Dr. James W. Hawkins, Jr., Dr. Robert R. Hessler, George L. Matson, Donald L. McCarty, Robert W. Oakes, Melvin J. Voigt, and Anton L. Witte.

In the fall of 1976, the building won for its architects, Liebhardt, Weston & Associates, A.I.A., La Jolla, a Prestressed Concrete Institute award for "outstanding use of precast concrete." General contractor for the library was Nielsen Construction Company, San Diego.

Scripps Institution of Oceanography

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SEAGOING OPERATIONS

The Fleet

Fiscal 1976-77 opened with research vessels *Melville, Thomas Washington, Alexander Agassiz, Alpha Helix,* and *Ellen B. Scripps* and research platforms ORB and FLIP operational. R/V *Dolphin* was out of service, and the cabin cruiser *Gianna* was being maintained outside Nimitz Marine Facility. Late in the year *Gianna* was sold to a private party. In all, the fleet spent 1,200 days at sea and traveled 105,276 nautical miles.

On July 1, 1976, *Melville* was at sea on Leg II of Pleiades Expedition, with Dr. Richard P. Von Herzen, Woods Hole Oceanographic Institution, Massachusetts, and Dr. James B. Corliss, Oregon State University, Corvallis, as scientific co-leaders. The program included box coring, piston coring, heat-flow measurement, and ocean-bottom seismology at the Galápagos spreading center west of the archipelago. Dr. Wolfgang H. Berger was scientific leader for Leg III, a one-month traverse between Balboa, Canal Zone, the western extension of the Galápagos structural trend, and Honolulu, on which box coring, preserving the water-sediment interface, piston coring, and heat-flow measurements were carried out. Drs. Jimmy L. Greenslate and Fred N. Spiess were scientific co-leaders for Leg IV and directed a deep-tow program and manganese nodule investigation from Honolulu to San Diego, arriving on September 23. A total of 15,605 nautical miles was logged during Pleiades Expedition (including 4,915 nautical miles during May and June 1976).

***R/V* Melville**

Melville remained in San Diego undergoing routine maintenance and upkeep until December 14, when F Drake 77 Expedition commenced. Dr. Jacqueline Mammerickx was the scientific leader for the first three weeks, which involved underway bathymetric and magnetic profiling on a San Diego-to-Valparaiso, Chile, transit ending January 7, 1977. Dr. Worth D. Nowlin, Texas A&M University, College Station, then directed water sampling and current-meter studies of the dynamic balance of the Antarctic circumpolar circulation between Cape Horn and the Palmer Peninsula during January–February as the 1976-77 field phase of the long-term International Southern Ocean Studies project. Edward A. Seifert, Oregon State University (OSU), was scientific leader for Leg III, in February, with underway geological profiling en route from Punta Arenas, Chile, to San Martin, Peru, prior to three months of nearshore, multi-ship investigations as the 1977 field phase of the several-year Coastal Upwelling Ecosystems Analysis (CUEA) project. Dr. David Helpern, University of Washington, Seattle, and Dr. Robert L. Smith, OSU, were scientific co-leaders for Leg IV-A, a one-week operation that involved setting and retrieving current-meter arrays and meteorology buoys off the Peruvian coast. Drs. Smith and Adriana J. Huyer, also of OSU, led Leg IV-B, in March, during which additional current meter and buoy work and hydrographic casts were completed. Drs. James C. Kelley, San Francisco State University, and John J. Walsh, Brook-

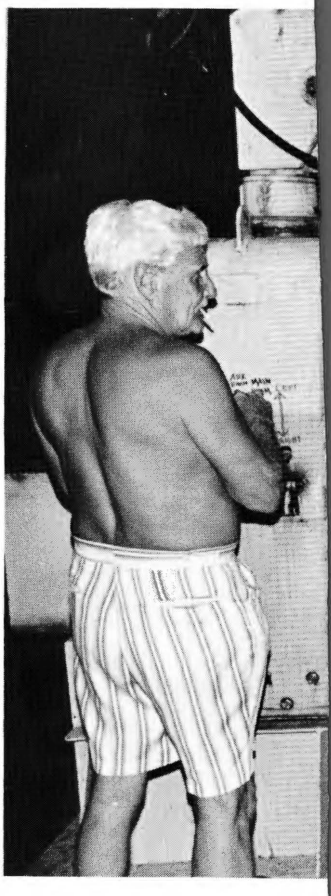
haven National Laboratory, New York, directed Leg IV-C, in April, during which hydrography, zooplankton net tows, and acoustic assessment of fish concentrations west of Peru were carried out. Legs IV-D and V consisted of upwelling temperature and chemical observations during May, with Drs. Louis A. Codispoti, University of Washington, and Theodore T. Packard, Bigelow Laboratory, West Boothbay Harbor, Maine, in charge. Leg VI took place between Balboa and San Diego during May and June, with Dr. Spiess and Dr. Kenneth C. Macdonald as scientific co-leaders. Their program involved underwater photography, deep-tow profiling, and monitoring seismic activity with ocean-bottom seismometers, and shore-based seismic stations, the latter operated by scientists from the Universidad Nacional de Mexico. Overall, *Melville* logged 36,847 nautical miles and 278 days at sea during the year.

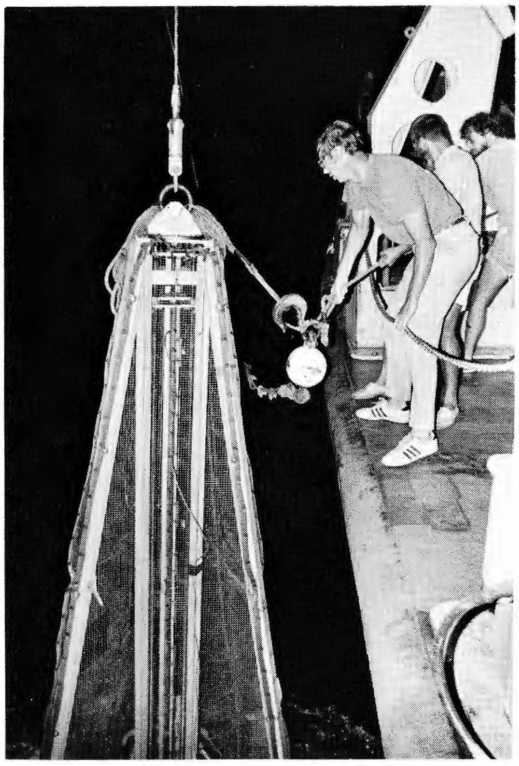
Thomas Washington was at sea early in July 1976, engaged in the predominantly geological-geophysical Indopac Expedition, coordinated by Dr. George G. Shor, Jr. Specifically she was on Leg V, Guam to Keelung, Taiwan, under the leadership of Dr. Shor, and working in cooperation with R/V *Chiu Lien* of National Taiwan University. Investigations included seismic refraction and reflection, acoustics, heat flow, and piston coring. Dr. Francis P. Shepard was chief scientist for Leg VI, in July and August, from Keelung to Subic Bay, Luzon, Philippines. Work included emplacement of current meters in submarine canyons, seismic profiling, and underway surveying. Leg VII, ending in Darwin, Australia, in August had Dr. Eli A. Silver, UC Santa Cruz, and Dr. William C. Patzert as cochief scientists. Work included a seismic reflection study of sediment thickness and structure in the Molucca Sea boundary region, plus Nansen bottle casts and current-meter observations of interocean mixing rates in the deep basins. Leg VIII, during September, again had Dr. Shor as chief scientist. Observations emphasized a seismic refraction study of the crust of the Banda Arc, Banda Sea, and Weber Deep, involving joint operations with Woods Hole's *Atlantis II.* On September 30 *Thomas Washington* arrived at the United States Naval Base in Guam, and was placed in a lay-up status for the final quarter of 1976.

The reactivated *Thomas Washington* departed Guam in January 1977, on Indopac Expedition Leg IX with Dr. A. Aristides Yayanos as chief scientist; work included hadal amphipod collecting and airgun testing in the vicinity of Challenger Deep, Mariana Trench. Drs. Silver and Russell W. Raitt, cochief scientists, then returned to the Molucca region for a month of seismic reflection, buoy seismic refraction, and dredging. In March, scientists aboard *Thomas Washington* employed Scripps's newly developed 24-channel seismic reflection system for sediment structure studies in the Andaman Sea and carried out ship-to-shore seismic refraction studies off Burma with the collaboration of Burmese geophysicists; leaders for this program were Drs. Joseph R. Curray and David G. Moore. There followed six weeks of work west of Sumatra as part of the Southeast Asia Seabed Assessment program. First, Dr. Curray and Dr. Daniel E. Karig, Cornell University, Ithaca, New York, conducted multichannel reflection profiling, piston coring, and heat flow on the trench flank and near Nias Island off Sumatra. Then Drs. Shor and Curray, working in collaboration with scientists on R/V *Samudera* of the Indonesian Institute of Sciences, Djakarta, carried out seismic refraction and reflection profiling and heat-flow measurements off the northwest coast of Sumatra. Dr. Shor then directed single-ship geological-geophysical work in the Banda Sea for several days before *Thomas Washington* traversed the western Pacific via Biak, West Irian, and Kwajalein en route to Hawaii. An expendable bathythermograph section along the North Equatorial Current was made prior to a late May arrival in Honolulu, where the geophysicists were replaced by biologists and geochemists. June was spent in free-vehicle deployment, water chemistry, and plankton investigations about 1,000 km north of Hawaii, under the direction of Dr. Kenneth L. Smith. During the year *Thomas Washington* logged 260 days at sea and steamed 35,165 nautical miles.

Alexander Agassiz participated on one two-month expedition, Farewell to Aggie, and two brief encores. She began a two-week run in August, under the direction of Dr. Jean H. Filloux, to Hilo, Hawaii, during which sea-floor electric and magnetic field recording instruments were emplaced. Late in August, she began a series of five photometer stations across the equatorial system and a 96-hour biological collecting station, all under the direction of Dr. Elizabeth Kampa Boden, and returned to Hilo in mid-September. Dr. Charles S. Cox then directed a three-week Hilo-to-San Diego traverse via the North Pacific Gyre, during which the electric and magnetic recording devices were retrieved and biological-physical oceanographic aspects of the gyre examined. There followed two short trips for physical and chemical oceanography and plankton sampling. *Alexander Agassiz* was sold in November and shortly thereafter was towed to her new home in Puget Sound, Washington. In her abbreviated year, she logged 75 days at sea and steamed 7,866 nautical miles.

R/V Thomas Washington





Investigations in eastern tropical Pacific during Leg 3 of Pleiades Expedition resulted in a variety of operations, as seen in pictures taken aboard R/V Melville *(clockwise from top left): Fred S. Dixon removes heat-flow recorder from piston corer weight-stand; as Dixon operates crane, John Crow, Massachusetts Institute of Technology graduate student, steadies thermistor probe that measures heat flow through the sea floor; Crow removes heat-flow thermistors from sharply bent piston core barrel lying alongside ship; Dr. Wolfgang H. Berger, chief scientist, assists graduate student William M. Jones, Oregon College of Education, and Thomas J. Walsh in attaching crane hook to mesh-enclosed tower used in measuring the shear strength of deep-sea sediments; hands of George D. Wilson use syringes to extract sediment slugs for pore water analysis from Hessler Mark II box core; Walsh holds free-fall sediment core in plastic liner, while Jones passes floats containing strobe lights to a helping hand.*

David L. Ripley

Alpha Helix, operated by Scripps as a National Facility for field biological-biochemical-biomedical research in regions where such capability is lacking, had a 365-day year on the Amazon River that will be described below.

Ellen B. Scripps made 35 sorties, ranging from one to twelve days at sea, during the year. Programs covered all disciplines, and emphasized student training and research, equipment development and deployment, and biological-geochemical collecting. Most of the scientists were Scripps students and staff, but investigators from three other University of California campuses–Irvine, Santa Cruz, and Santa Barbara–and San Diego State University were accommodated. In operations ranging from the Oregon border on the north to Magdalena Bay, Baja California, on the south, *Ellen B. Scripps* logged 133 days at sea and steamed 10,963 nautical miles.

Research platforms FLIP and ORB each have assigned captains, but share a crew. With the exception of one seven-day FLIP operation under the direction of Dr. Steven McConnell, University of Washington, they were engaged entirely in research for the Marine Physical Laboratory. FLIP's operations on long-range acoustic propagation and on internal-wave studies were directed by Dr. Frederick H. Fisher or Dr. G. Thomas Kaye and by Dr. Robert Pinkel, respectively. FLIP was towed 2,213 nautical miles and logged 69 days at sea; it spent one month in overhaul in a local shipyard. ORB spent the first seven months in port undergoing major modifications to its heave-compensation system. Commencing in February, ORB began a series of tests with Advanced Detection Array (ADA) under the direction of Dr. Victor C. Anderson and Daniel K. Gibson, and Brett Castile, UC San Diego graduate student, made acoustic reverberation studies. During the year ORB logged 20 days at sea and was towed 155 nautical miles.

Nimitz Marine Facility

With Scripps's three expeditionary vessels away for all or much of the year, the operating base at Point Loma was able to provide accommodation for short visits of research vessels from sister west coast institutions and one foreign ship, *Le Noroit* of Brest, France, which carried out sea-floor studies for Centre National Pour l'Exploitation des Oceans (CNEXO).

Seven senior and long-time marine facilities employees retired during the year. Longest in point of service were John C. Dullaghan, assistant manager of marine operations, and Monroe I. Richardson, dean of the shoreside shop force, with 19 and 25 years, respectively.

R/P ORB

Ship Construction

Design was completed–and at year's end a contract was being negotiated–for the construction of a 52 m, medium-sized oceanographic vessel to replace and exceed the capabilities of *Alexander Agassiz.* The vessel, to be christened *New Horizon,* is scheduled for completion by mid-1978 and should be used for research cruises shortly thereafter.

Funds for design and construction of *New Horizon* were provided by the State of California, the first time the state has funded the construction of a Scripps ship. Fully equipped, her cost will be about $4 million; nearly one-fifth of that sum is for outfitting. Much of her schedule will involve Scripps's Marine Life Research Group (MLRG) program, which is part of the California Cooperative Oceanic Fisheries Investigation, and state funding is expected to cover a large share of her operation. Hence, she will frequently carry out MLRG cruises, between the Canadian border and the tip of Baja California. Nevertheless, *New Horizon* will be capable of operation in any part of the ocean except the polar seas; she will be used mostly throughout the eastern Pacific.

New Horizon is similar in many features to the University of Miami's 52 m *Columbus Iselin.* Marine architects for both ships were Rudolph Matzer and Associates, Inc., Jacksonville, Florida. Scripps has a *New Horizon* advisory committee chaired by Dr. William A. Nierenberg; through that committee the architect received input and review from more than 50 seagoing Scripps scientists, engineers, and technicians, plus Nimitz Marine Facility specialists. Notable in providing ideas, initiative, impetus, and counsel during the many months of design development were Dr. Robert A. Knox, Richard Schwartzlose, and William C. King, Jr.

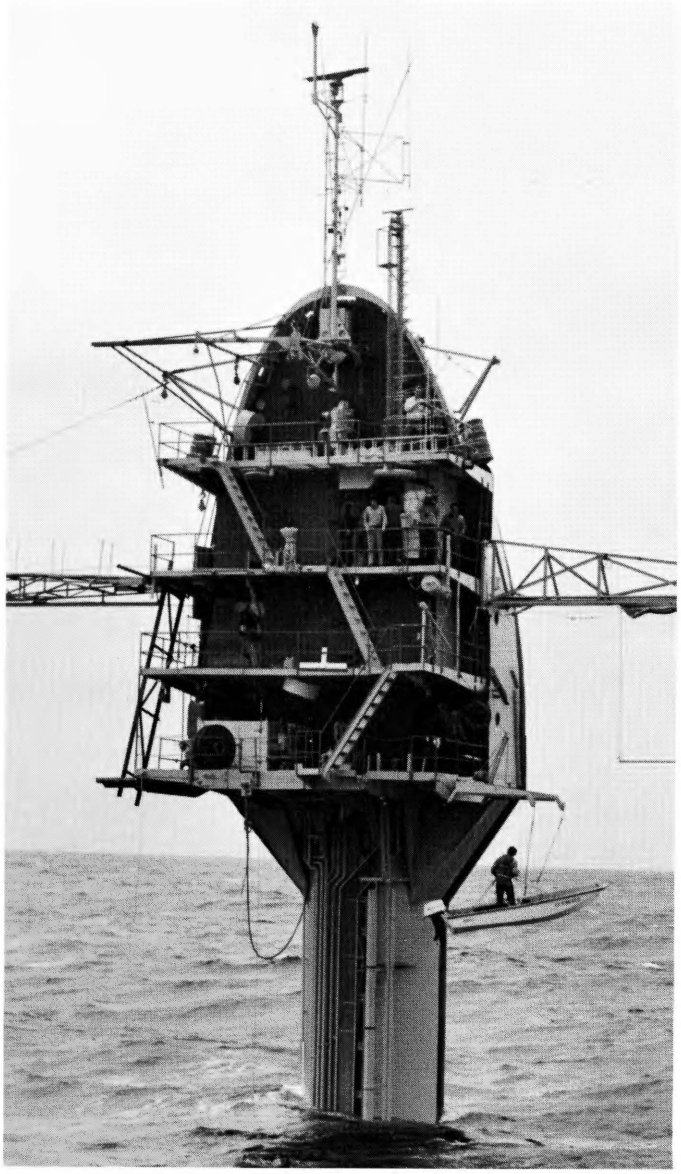
New Horizon will be only slightly shorter than *Alexander Agassiz,* but of less than 300-gross-ton displacement. With a crew of 12 and a scientific party of 13, she should economically perform complex field programs for sustained periods. As designed, *New Horizon* will have a 7,000-nautical-mile range and a 30-day endurance at 12 knots. She is twin-screw, and diesel, with bow thruster and after-control station. Heavy equipment includes three cranes, with a capacity up to 20 tons, a hydraulic boom, hydraulic A-frame, a trawl winch with 13 mm wire, and two hydrographic winches.

Alpha Helix Program

Alpha Helix, though a vessel of Scripps's fleet, is operated by the institution as a national oceanographic facility almost entirely funded by the National Science Foundation. Scientific direction is provided by an *Alpha Helix* review committee that includes one member from Scripps. The program is managed through the Ship Operations and Marine Technical Support Division; its staff consists of two resident marine technicians, who alternate aboard *Alpha*

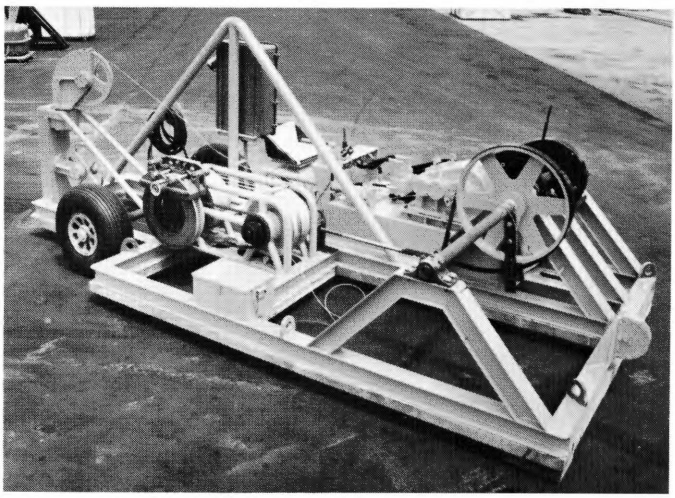
R/V Alpha Helix

R/V Alexander Agassiz



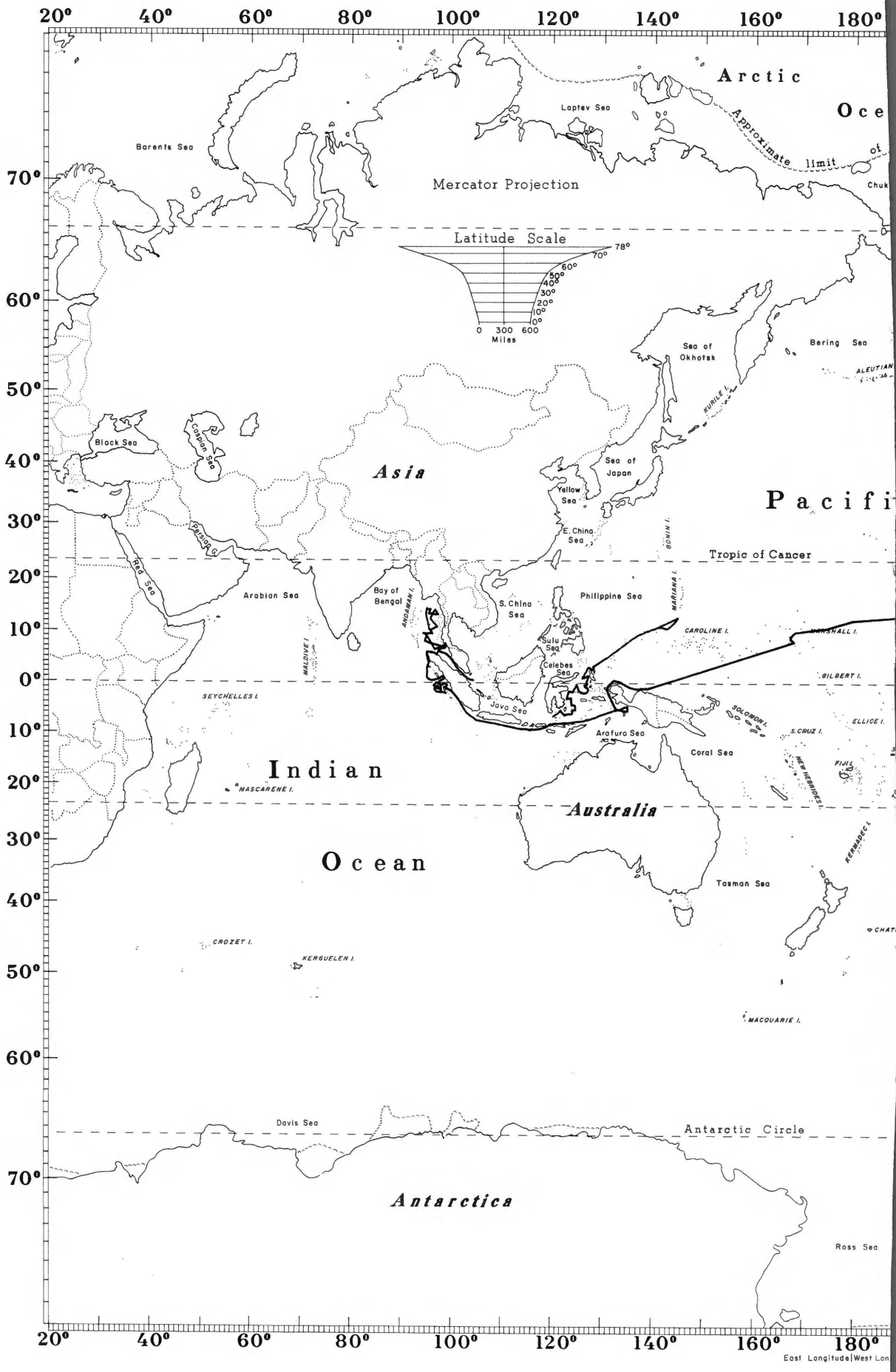
R/P FLIP

R/V Ellen B. Scripps



Device for spooling heavy cable under tension, designed and built by Monroe I. Richardson and his colleagues at Nimitz Marine Facility.

Nimitz Marine Facility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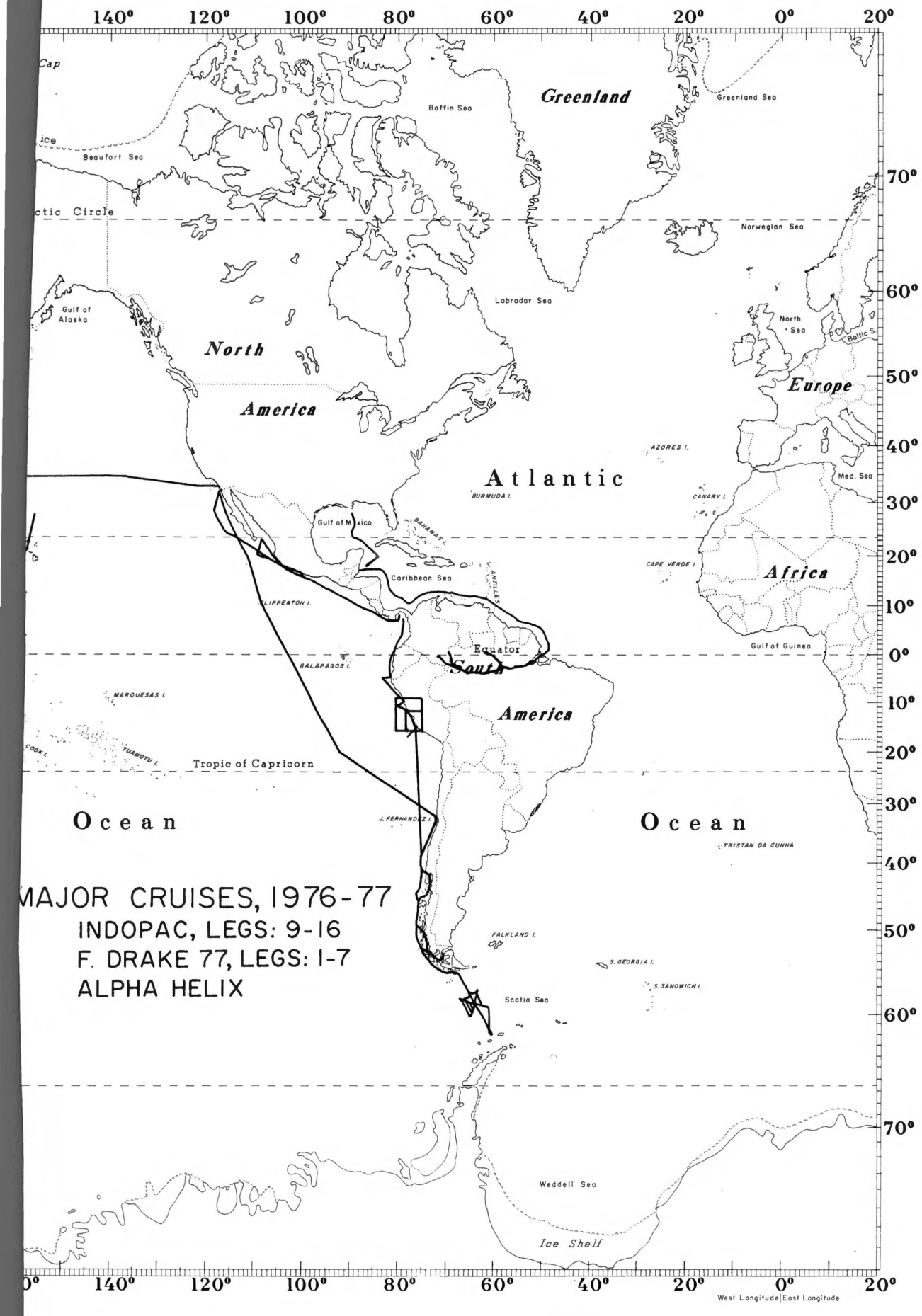
Tasman Sea
40°
CROZET I.
KERGUELEN I.
50°
MACQUARIE I.
60°
Davis Sea
Antarctic Circle
70°
Antarctica
Ross Sea
20° 40° 60° 80° 100° 120° 140° 160° 180°
East Longitude | West Lon

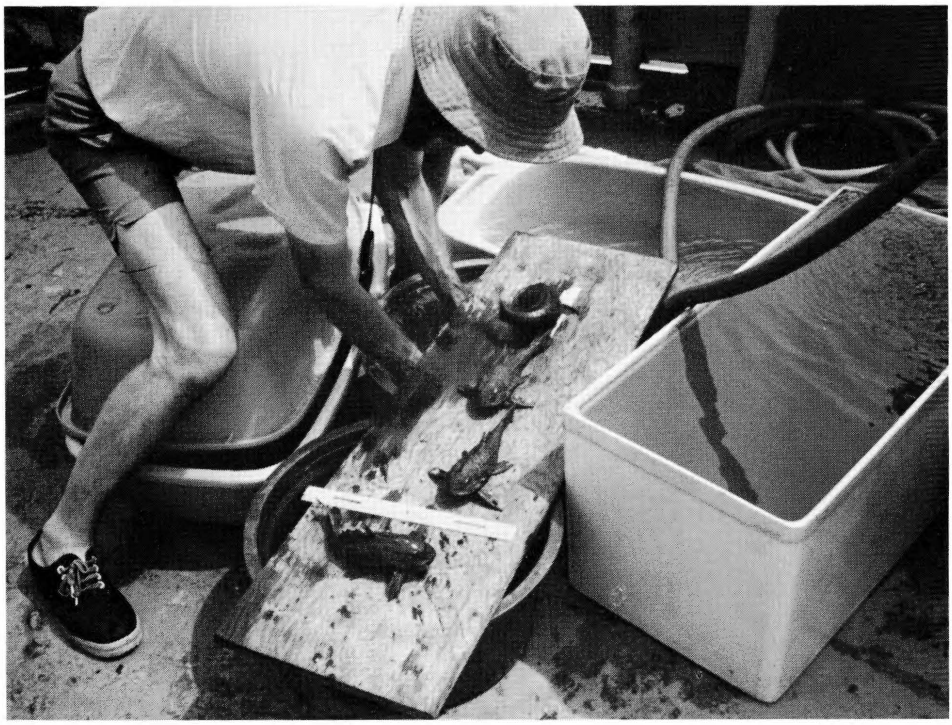


William L. Crocker, Jr.

Helix, and a program office representative.

On July 1 *Alpha Helix* was between Manaus, Brazil, and Leticia, Colombia, en route up the Amazon River on a program, under the direction of Dr. John M. Edmond, Massachusetts Institute of Technology (MIT), Cambridge, that began near the river's mouth and would extend nearly 4,000 km upriver to Iquitos, Peru.

The joint MIT-U.S. Geological Survey group carried out a geochemical sampling program and sediment load study to relate provenance, flow rate, and basin vegetation to water characteristics and organic substances in the Amazon itself and the various tributaries. *Alpha Helix*'s run occurred during a near-record high stage of the Amazon; Manaus and some riverside villages were partially inundated. A similar program, by the same group, was carried out 11 months later on the closing downstream traverse.



Under the direction of Dr. James V. Neel, University of Michigan Medical School, Ann Arbor, studies of six Amerindian tribes were made from mid-July through late August as *Alpha Helix* successively shifted base downriver. Expedition scientists probed and measured some 3,000 indigenous inhabitants and drew more than 2,800 blood samples for genetic and seroepidemiological examination. Ancillary activities included collection of demographic and linguistic material. Thereafter, at Manaus, *Alpha Helix* was employed for several days by Brazilian researchers of the Instituto Nacional de Pesquisas do Amazonia.

Alpha Helix's September-October operations, in the vicinity of Manaus, Lake Janauacá, and the Solimões and Negro rivers, were funded by the National Research Council of Canada and were directed by Drs. David Randall and Peter Hochachka, University of British Columbia, Vancouver. Laboratory experiments were conducted to study the pulmonary, kidney, and other physiological characteristics of aquatic vertebrates long ago adapted to air-breathing behavior; the pond-living lungfish *(Lepidosiren),* limbless amphibians (Apoda), the eel-like *Symbranchus,* and the very large arapaima, an air-breathing osteoglossid that was compared with the water-breathing osteoglossid, aruana. Other more intrepid investigators examined the anaconda and caiman.

In an informal ceremony June 24, 1977, held at Nimitz Marine Facility, plaques were presented to seven Nimitz Marine Facility retirees – whose service to the institution totaled 89 years – by William C. King, Jr., port engineer (left), and Capt. Peter S. Branson (right), manager of marine operations. Others (from left) were John C. Dullaghan, 19 years; Monroe I. Richardson, 25 years; Paul W. Pritchard, 11 years; and Mrs. Robert A. Briggs, who accepted on behalf of her husband, who served ten years. Also absent were William W. Ferrell, 11 years; Jack O. Nelson, ten years; and Samuel W. White, three years.

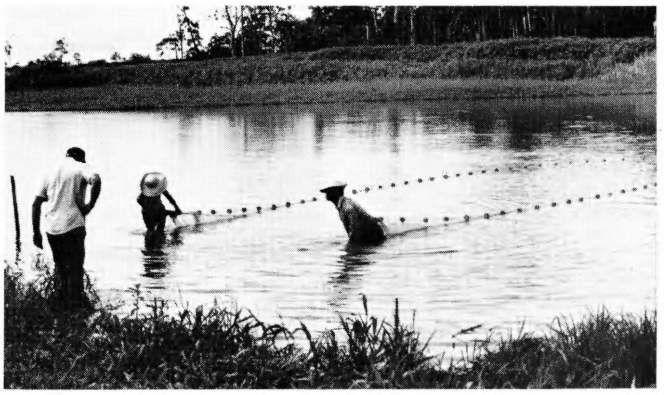
In November and December, Dr. Austen F. Riggs, University of Texas, Austin, led a group conducting equilibrium and kinetic studies of oxygen-binding by hemoglobin in the blood of *Lepidosiren, Symbranchus,* the aruana, several apodans, and more than 100 species of Amazonian fish as well as 50 fish species form Lake Janauacá.

In January 1977, an international team of physiologists and ophthalmologists, under the leadership of Dr. Colin J. A. Nicol, University of Texas, Port Aransas, studied the structure, function, and retinal pigments of the eyes of fish and fresh-water dolphin from the Solimões River and Lake Janauacá. Correlative studies involved measurement of light transmission and turbidity in the various bodies of water.

A one-month run upriver, Manaus to Iquitos, was led by Dr. Ghillean T. Prance, New York Botanical Gardens, during which disc gel electrophoresis of riverbank plants was accomplished,

more than 600 plant specimens were collected, and scientists of the River Continuum Project examined photosynthesis in the river water column, collected caddis flies on the smaller streams, calculated the river's sediment load, and obtained nearly 1,600 blood samples for studies of malaria and parasites.

From late March through mid-May *Alpha Helix* was based principally far upriver at Pebas, Peru, on a botanical and pharmacological study of hallucinogenic plants led by Dr. Richard E. Schultes, Harvard Botanical Museum, Cambridge, Massachusetts. Bioactive and apparently hallucinogenic compounds from leaves, fungi, and bark collected



A wide variety of scientific research was achieved between June 1976 and mid-May 1977 during the Amazon Expedition, in which R/V Alpha Helix ***served as operational base for investigations conducted along the Amazon River, Rio Solimões, and Rio Negro (see accompanying text). Clockwise, from top left (opposite page): Dr. Casimir Lindsey, University of Manitoba, Winnipeg, Canada, examines three "walking" catfish in studies of their terrestrial locomotion (Dr. Grant R. Bartlett photo). Armored, air-breathing catfish is held by Dr. E. Donald Stevens, University of Guelph, Ontario, Canada, who investigated its respiratory physiology. Spines help fish defend against predators (Dr. Charles F. Phleger photo). Scientists seine a pond to collect a suite of fish for studies of their visual capabilities and for taxonomic purposes. From left: Dr. Frank Seabury, The Citadel, Charleston, South Carolina, and Drs. Narzio A. Menezes and Heraldo A. Britski, both of University of São Paulo, Brazil (Dennis M. Popp photo). Graduate student Douglas H. Macintyre, University of British Columbia, Vancouver, Canada, displays 4-m anaconda, whose respiratory physiology was under study (Steven M. Stinchcomb photo). The paca, or spotted cavy, is a plant-eating, nocturnal rodent hunted for food by man and other animals. The paca can attain a weight of up to nine kg and a length of one m (Dr. Grant R. Bartlett photo).***

by botanists in remote areas were isolated and analyzed aboard to identify the active agent. Contacts with tribal members provided observational data on usage of and invitations to folk ceremonies. Meanwhile, scientists from the U. S. National Institutes of Health were collecting poisonous fish, frogs, and varied insects to analyze and identify the toxins.

The work in Peru was followed by a three-week run to the Amazon's mouth at Belém, directed by Dr. Edmond, repeating the earlier observations of the river system's characteristics. Belém was reached in June, completing the eighth and final phase of *Alpha Helix*'s Amazon 1976-1977 program.

During June, *Alpha Helix* proceeded northwest along the northern coast of South America, while zooplankton collections and hydrographic observations were being made off Surinam and the islands of the Netherlands Antilles, under the direction of Dr. Abraham Fleminger. Hoped-for study of the anaerobic Carioco Trench was aborted because of clearance uncertainties. *Alpha Helix* reached Colón, Canal Zone, on July 1, having logged 9,583 nautical miles and 365 days.

GRADUATE DEPARTMENT

Graduate education at the Scripps Institution and its predecessors can be traced back to before 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 UC San Diego became a degree-granting campus of the university.

In the early days of UC San Diego, 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 the requirements of the department as a whole.

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 graduate department to provide maximum flexibility in meeting the specific interests of individual students.

During the year covered by this report, the graduate department was chaired by Dr. Fred N. Spiess, until April 1977. Dr. Myrl C. Hendershott, who served as vice-chairman, was appointed acting chairman in May 1977. The department includes 58 regular faculty members and five adjunct professors. In addition, 15 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 and include 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 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. 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 student.

Biological Oceanography (Dr. Robert R. Hessler). Biological oceanographers are concerned with the interactions of populations of marine organisms 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, mathematical ecology, fisheries biology, taxonomy and zoogeography of oceanic organisms, and behavior as it affects distribution and sampling problems.

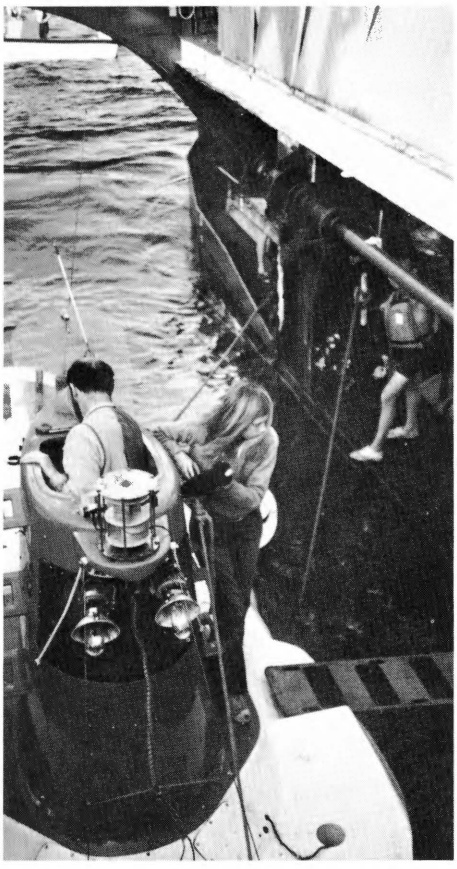
Geophysics (Dr. Robert L. Parker). This curriculum is designed to develop the ability of the physicist (theoretician or experimentalist) to contribute to man's understanding of the sea, the solid earth on which it moves, and the atmosphere with which it interacts. The program initially assists the student in assimilating 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 insight into the problems of the structure of the earth and the nature of energy propagation and exchanges that take place

within it.

Marine Biology (Dr. George N. Somero). The marine biology curriculum places particular emphasis on the manners in which marine organisms – animals, plants, and prokaryotes – are adapted to the physical, chemical, and biological conditions of the marine environment. Research and teaching encompass a wide range of biological disciplines, including behavior, neurobiology, developmental biology, and comparative physiology/biochemistry.

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/Dr. H. William Menard). 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 the atmosphere. Principal subprograms 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.



Graduate student Kathleen Crane leaves research submersible Alvin ***after a nearly 10-hour, 2,500-m dive in the Galápagos Rift Zone, 644 km west of Ecuador, during a spring 1977 expedition. She was the first woman to see marine organisms thriving in deep-ocean hot springs and mineral-rich mounds of manganese, nickel, and copper. Scripps had identified the springs from surveys of the area in mid-1976 on Pleiades Expedition.*** Alvin ***is operated by Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.***

Mitchel Lyle, Oregon State University

New Year's Eve 1976 found graduate student John S. Oliver (left); Dr. Davida Kellogg, University of Maine (center); Peter N. Slattery, seen in ice hole; and Dr. Theodore D. Foster, who took the photograph, near McMurdo Sound, in Antarctica. Group was preparing for a dive under the 3½-m-thick sea ice in about 20 m of water to implant and retrieve amphipod traps, two of which appear at right center. This work was part of ongoing research on marine ecology of the region, conducted by Dr. Paul K. Dayton's group under the National Science Foundation's Antarctic Polar Program.

Dr. Theodore D. Foster

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; the properties and propagation of ocean waves; and the influence of surf on nearshore currents and the transport of sediments.

GRADUATE STUDENTS AND DEGREE RECIPIENTS. In the fall of 1976, 33 new students were admitted to graduate study. Of these, 2 were in marine biology, 8 in geological sciences, 4 in marine chemistry, 7 in biological oceanography, 6 in geophysics, 2 in physical oceanography, and 4 in applied ocean sciences. Sixteen were California residents, 13 were from out-of-state, and 4 were from foreign countries. Enrollment at the start of the 1976 academic year totaled 188 students. Three Master of Science degrees and 25 Doctor of Philosophy degrees were awarded by UC San Diego to students who completed advanced studies at Scripps during the academic year 1976-77. The names of degree recipients, the titles of doctoral dissertations, and the names and new positions of PhDs are listed in Appendix E.

RESEARCH ACTIVITIES

Deep Sea Drilling Project

During fiscal 1976-77, Deep Sea Drilling Project (DSDP)/ International Phase of Ocean Drilling (IPOD) completed seven scientific legs aboard drilling vessel (D/ V) *Glomar Challenger*, operating mainly in the Atlantic Ocean.

The aim of DSDP, which began in August 1968, is to increase man's knowledge of the earth–the age, history and processes of development of the ocean basins, and the structure and composition of the oceanic crust. During the nine-year history of the project, nearly 10,000 cores (49,000 m of sediment) have been recovered for study and analysis.

IPOD addresses itself to the "how" as a follow-on to DSDP's previous efforts to determine the "what" of ocean dynamics. As a fourth phase of the ongoing DSDP, IPOD is a program designed to enable scientists to drill deeper into the earth's oceanic crust than has ever been done before and to initiate studies of deep sediments of the oceanic margins. It is a probe to determine how new ocean crust is formed and destroyed during continental drift and sea-floor spreading. IPOD results will be used to evaluate the hypothesis currently being developed concerning the history of the world's ocean basins.

On Leg 49, D/ V *Glomar Challenger* operated along the mid-Atlantic Ridge where drilling was accomplished into younger ocean crust than had ever before been attempted. At one site, a crustal layer was drilled, the rocks of which were about one million years old, less than a third as old as any other crust the project had sampled in its nine-year history.

A marathon effort was undertaken on Leg 50 to drill a very deep exploratory core hole into the sediments beneath the ocean floor at the foot of the continental slope off the Atlantic Coast of North Africa. After nearly 40 days of continuous drilling in water 4,200 m deep, the hole was abandoned at a depth of 1,624 m below the sea floor. Although this fell short of the original target depth of 2,500 m, it was deep enough to provide new insight into the geological evolution of continental margins and into the ways plant debris washed into the sea is gradually converted into petroleum as it is buried under more and more layers of sediment.

The vessel had to leave the site and make a brief port call in the Madeira Islands for a change of crew. The ship then retraced its several- hundred-kilometer route back to the same spot and replaced the drill pipe in the hole it had left four days previously. The event marked the first time that the ship had left a hole unfinished, sailed several hundred kilometers round trip and reentered exactly the same hole especially in such a remarkably short time.

Legs 51, 52, and 53 signaled another precedent in the history of the project; for the first time, three consecutive legs were devoted to a single drilling effort. The area involved was located at the southern end of the Bermuda Rise, about 725 km south of Bermuda. The goal of this multiple effort was to enhance IPOD's long-term study of the processes by which new oceanic crust, which constitutes 60 percent of the rocks of the earth's surface, is formed along a never-healing fracture between continually separating plates of lithosphere. During Legs 51, 52, and 53 penetration was achieved deep into older oceanic crust of the western North Atlantic sea floor, a basin where some of the oldest rocks in the world are found.

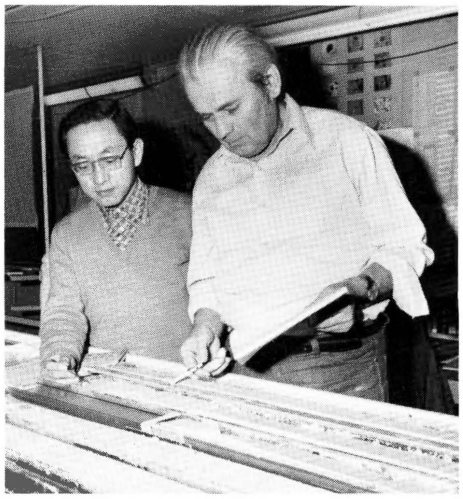
On Leg 52 the greatest water depth at which reentry has ever been accomplished took place. The feat occurred after reentry cones were placed at two different locations on the sea floor in water depths of just under 5,500 m as the ship held station over the Bermuda Rise. Reentry was accomplished several times in order to permit replacement of worn-out drill bits.

In reentering the hole begun by Leg 52 scientists, the Leg 53 shipboard party drilled almost 300 m deeper, using six more reentries, to a total basement penetration of over one-half a kilometer, the deepest penetration into old crust ever made by DSDP.

With the aid of shipboard laboratory equipment for measuring the physical and chemical properties of recovered material, the scientists have pieced together a remarkable record of the eruptive activity and the massive spasms of tectonic movement that accompany generation and "spreading" of crust at the axial zone of formation. The picture is complex, but high recovery of the drilled rocks (72 percent) has provided an unprecedented opportunity to interpret ancient geological processes at spreading axes and compare these with activity at the present time.

The critical part of the work done during Leg 54, which was the final voyage of the year, was drilling an active geothermal area in the deep-sea floor at the Galápagos Rift near Darwin's famous "Islands of the Equator" in the Pacific Ocean. Other work during the leg was done along a related major submarine volcanic mountain system–the East Pacific Rise–about 1,600 km southwest of Mexico City. The objective along the East Pacific Rise was to determine the composition, magnetic properties, structure, and evolution of the rise crest by drilling into the volcanic rocks on the sea floor. After Leg 54, D/ V *Glomar Challenger* made port in Los Angeles where she underwent an extended, but routine, shipyard overhaul.

A remarkable engineering feat was accomplished by project technicians during Leg 53 when an array of tools, broken off in a borehole approximately 6,400 m beneath the ship's keel, was successfully retrieved. The total weight of the retrieved array was over 25 tons. The tools had become disengaged from the drill pipe during routine operations. Although infrequent, such incidents can be costly and have, in the past, forced operations at the given hole to be suspended and the core hole abandoned with obvious setbacks in the immediate scientific endeavors.



Drs. Hideo Kagami (left), Ocean Research Institute, Tokyo, and P.P. Timofeev, USSR Academy of Sciences, Moscow, compare notes on sediment recovered from Site 402 of Deep Sea Drilling Project. They conferred in Sediment Laboratory aboard D/V **Glomar Challenger.**

Deep Sea Drilling Project

Scripps manages DSDP, which is funded by the National Science Foundation (NSF), through a contract with the University of California. The project is part of NSF's Ocean Sediment Coring Program. The University of California subcontracts with Global Marine Inc., Los Angeles, to accomplish actual drilling and coring using their D/ V *Glomar Challenger.* Dr. Melvin N. A. Peterson is project manager and Dr. David G. Moore is chief scientist.

Scientific advice is furnished to the project by panels from Joint Oceanographic Institutions of Deep Earth Sampling (JOIDES). JOIDES members are the Lamont-Doherty Geological Observatory, Columbia University, New York; Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Florida; Department of Oceanography, University of Washington, Seattle; Woods Hole Oceanographic Institution, Massachusetts; USSR Academy of Sciences, Moscow; Bundesanstalt für Geowissenschaften und Rohstoffe, Federal Republic of Germany; Ocean Research Institute, University of Tokyo, Japan; Hawaii Institute of Geophysics, University of Hawaii, Honolulu; Oregon State University, Corvallis; Texas A & M University, College Station; University of Rhode Island, Kingston; Natural Environmental Research Council of the United Kingdom; Centre National pour l'Exploitation des Océans (CNEXO), France, and Scripps.

Geological Research Division

Work in the Geological Research Division has covered a variety of areas: from geological investigations in the Indian Ocean to discovery of a possible theory as to why dinosaurs became extinct millions of years ago.

Dr. Joseph R. Curray and his associates, Drs. David G. Moore, LeRoy M. Dorman, and Lawrence A. Lawver and Frans J. Emmel and graduate students Carrel A. Ramsey and Robert M. Kieckhefer, have continued their investigations of the geology and geophysics of the northeastern Indian Ocean, including the Bay of Bengal, the Andaman Sea, and the Sunda Arc. Dr. J. Murray McDonald completed his doctoral dissertation working with this group on geology and geophysics of the Nicobar Fan (the eastern lobe of the Bengal Fan) that is between the Sunda Trench and the Ninetyeast Ridge. His work has shown the probable location of the extinct spreading centers for Paleogene sea-floor spreading east of the Ninetyeast Ridge. Other work completed during this year includes a preliminary tectonic interpretation of Burma and the Andaman Sea; this suggests that the eastern part of the central valley of Burma, as the Andaman Sea, is underlain by Neogene oceanic crust. A small lithospheric plate, which includes western Burma, the Andaman-Nicobar Ridge, and southwestern Sumatra, has moved northwestward with respect to the continental mass of eastern Burma and the Malay Peninsula.

During March 1977, Drs. Curray and Moore led Leg 11 of Indopac Expedition in further geological and geophysical work in the Andaman Sea. Work this year included a cooperative study with geophysicists of the Burmese Myanma Oil Corporation on deep structure of the Burmese continental shelf at the north end of the Andaman Sea. Dr. U Aung Tin U, chief geophysicist of Myanma, worked on *Thomas Washington* with the Scripps scientists, while Scripps assisted the Burmese in receiving refraction shots from *Thomas Washington* at a station on the shores of the Irrawaddy Delta. During April 1977, Dr. Curray, working with Dr. Daniel E. Karig, Cornell University, New York, and Dr. George G. Shor, Jr., conducted geophysical investigations of the Sunda Transect extending from the Indian Ocean floor, across the Sunda Trench, through Nias Island, to the shoreline of central Sumatra. The first use of Scripps's new, 24-channel, digital, seismic-reflection system occurred off Sumatra and in the Andaman Sea. This system was assembled at Scripps from components donated by Exxon Corporation and coordinated with a high-density format magnetic taping system and minicomputer, with funding from Scripps Industrial Associates and Cecil H. and Ida M. Green Foundation. This first field use was very successful. A digital four-channel shipboard real-time monitoring system has been completed and tested. Various portions of these surveys are now being processed by members of Scripps Industrial Associates, while GRD is proceeding with development of its own in-house processing capability.

Dr. Curray, Prof. M. Audley-Charles, Queen Mary College, London, and Dr.

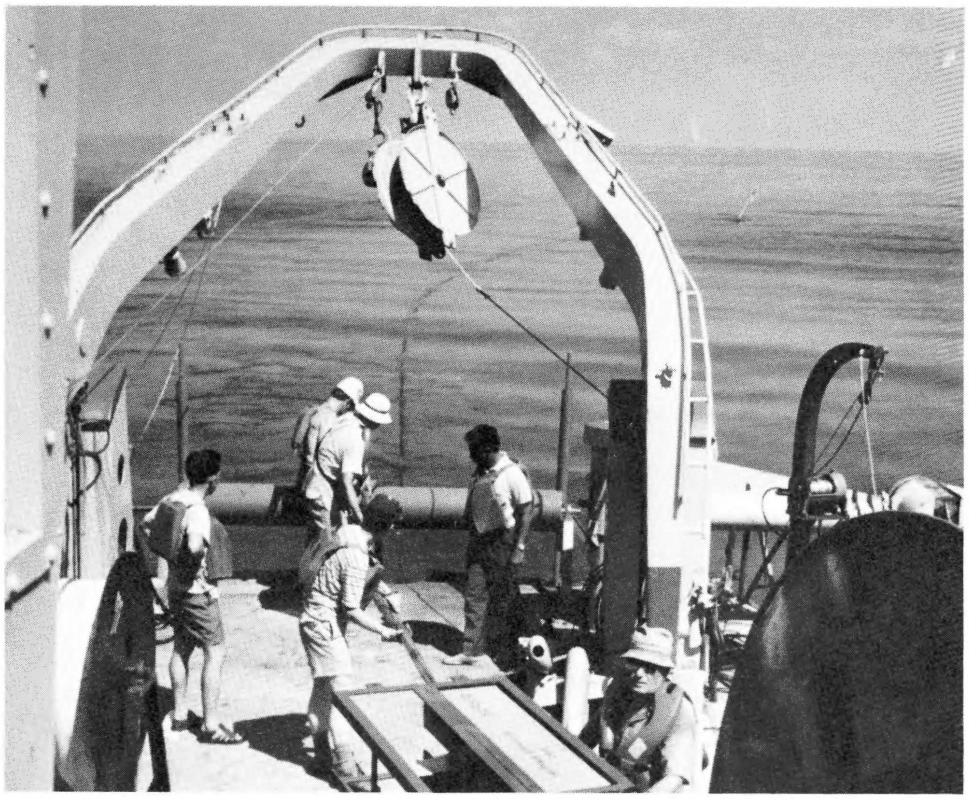
When ship personnel inspect or repair thruster system of D/V Glomar Challenger, ***a circular piece of equipment, called a coffer dam, is used to shut off flow of water into the ship's forward thrusters. Here, the "dam" is being lowered into place during vessel's port stop at San Juan, Puerto Rico, harbor.***

Deep Sea Drilling Project

Graham Evans, Imperial College, London, also completed an analysis of tectonic settings of major deltas, both in the modern world and in the geological record. While many major modern deltas are located at passive continental margins, many other modern deltas and most ancient deltas, which have been identified in the geological record, are located either at the landward edge of mobile belts or where these so-called Alpino-type subduction zones intersect continental margins.

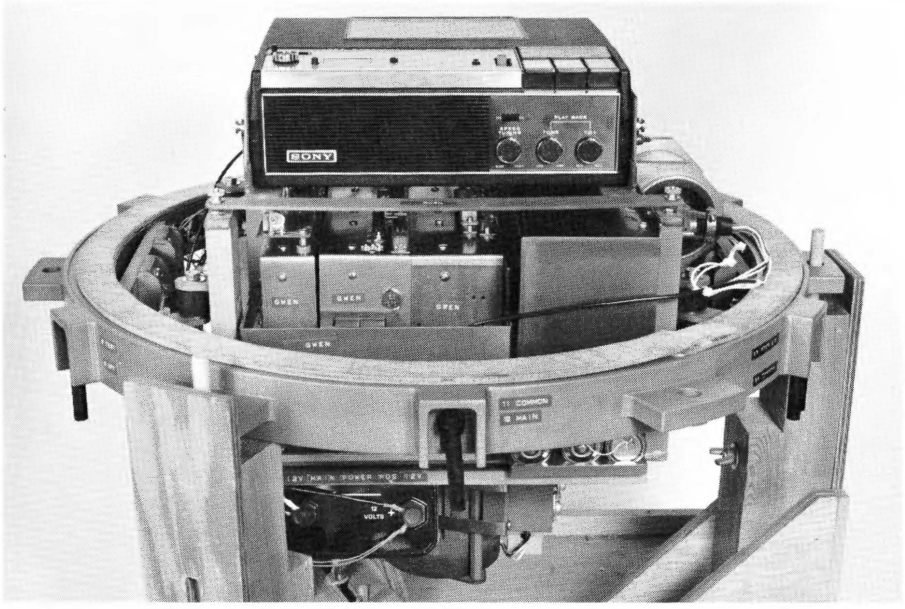
The ocean-bottom seismograph group, consisting of Drs. James N. Brune, Dorman, Thomas H. Jordan, Kenneth C. Macdonald, Robert D. Moore, and John A. Orcutt, and graduate students Marilee Henry, Chin-yen Huang, Paul G. Silver, Paul Spudich, and Keith A. Sverdrup, has participated in four cruises since the last report.

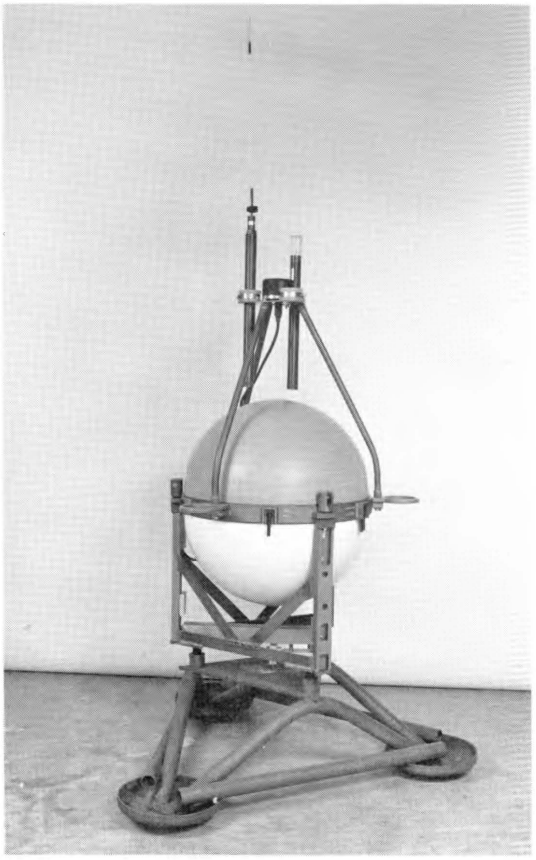
The first of these was into the Pacific Basin east of Hawaii to conduct a long seismic refraction profile using artificial sources. The maximum source-receiver distance achieved was about 500 km; information about the earth structure to a depth of 50 km was obtained. Dr. Dorman is coordinating a cooperative experiment this fall to extend the line to about 2,000 km. Other participants include the University of Hawaii, Honolulu; University of Texas, Galveston;



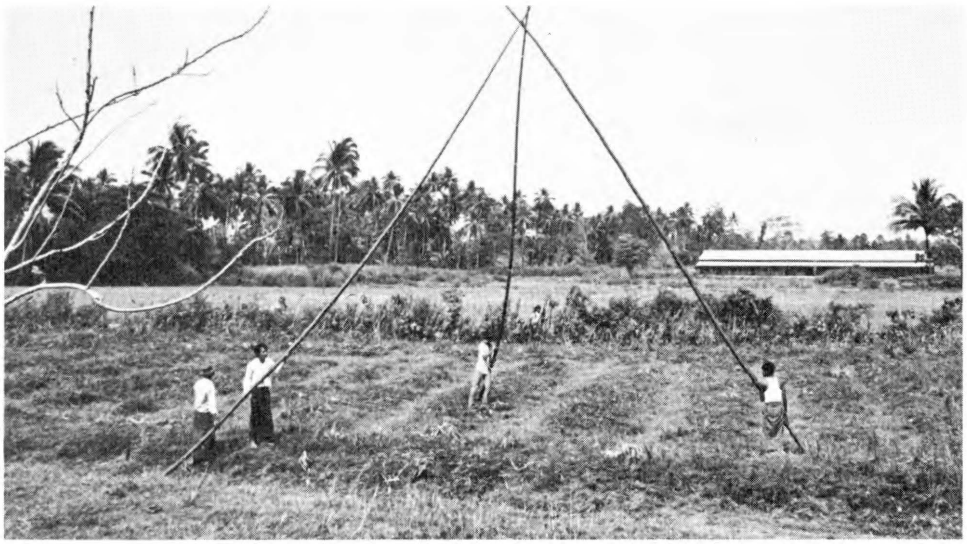
During geological and geophysical studies of the Andaman Sea, south of Burma, on Leg 11 of Indopac Expedition, technicians are shown deploying 2-km-long, seismic-reflection, hydrophone streamer from R/V Thomas Washington. *The streamer, paying out from reel at lower right, passes through A-frame and into ocean. Surface tail buoy is barely visible to right of A-frame, about 100 m distant.*

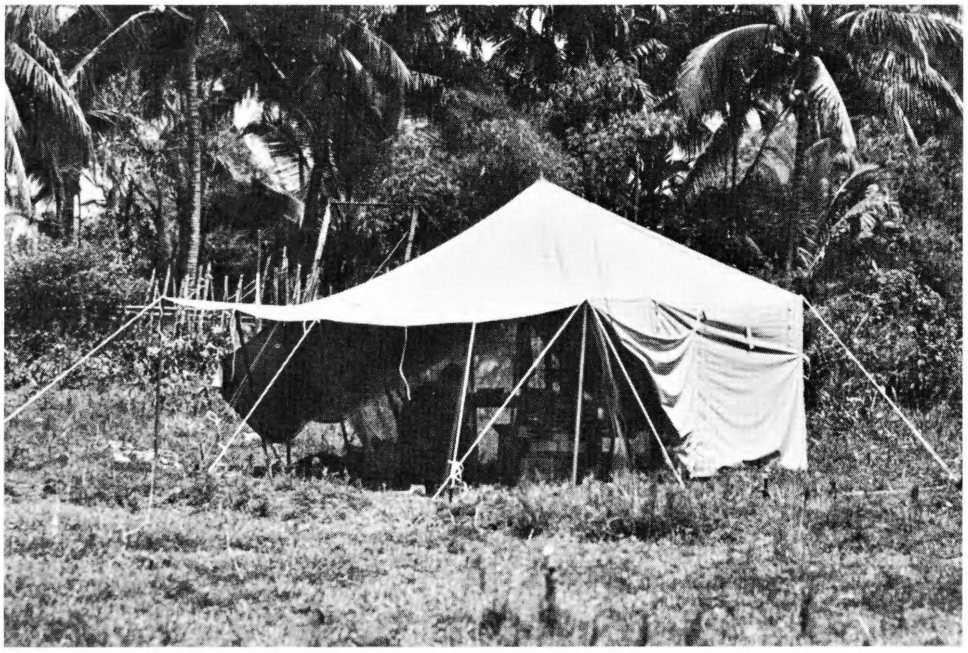
Robert M. Kieckhefer





Work off Mexico on the axis of the Middle America Trench, directed by Drs. Kenneth C. Macdonald and Thomas H. Jordan during F. Drake 77 Expedition, utilized ocean-bottom seismometers (OBM) to record earthquakes and determine their precise locations for studies of the earth's structure, the mechanism of earthquakes, and the motion of crustal plates. Capsule is shown with its tripod ballast as it appears before deployment from a vessel as a free-vehicle and while it is on the sea floor. The device can record seismic events for about a month, and then, on acoustic command, jettison its tripod ballast, and return to the sea surface for recovery. Capsule's internal view shows modified, portable, reel-to-reel recorder mounted above various power mechanisms and electronic gear that senses events and triggers the recorder. Unit can be interrogated for information on the status of equipment or data recorded. OBMs are used for several Scripps research projects.





Scripps's geological and geophysical investigations of the Andaman Sea during Leg 11 of Indopac Expedition included a cooperative study with Burmese Myanma Oil Corp. geophysicists on deep structure of Burmese continental shelf at north end of sea. Myanma's chief geophysicist, U Aung Tin U, worked aboard R/V Thomas Washington *with Scripps scientists, while Paul O'Neill assisted the Burmese in receiving refraction shots at Ama Village, on shores of Irrawaddy Delta, from the ship, which was almost 200 km away. Burmese are setting up bamboo antenna used in receiving shots from ship. Receiving-station tent was located at midpoint of 2-km-long Geophone array used by Burmese seismic team in recording the shots.*

Paul O'Neill

University of Japan, Tokyo, and University of Washington, Seattle, using ships from Scripps, the University of Hawaii, and the U.S. Coast Guard. The next two cruises were to the East Pacific Rise at 9°N and 11°S to compare the seismic structure of the rise at locations with different spreading rates and to conduct a detailed survey of a proposed drilling site of the Deep Sea Drilling Project. Earthquakes at boundaries of oceanic plates have been studied in cruises led by Dr. Macdonald and Dr. William A. Prothero, UC Santa Barbara, to the Gorda Rise, off northern California, and by Drs. Jordan and Macdonald to the Middle America Trench, off Mexico.

During the year, Dr. Macdonald was involved in studies of volcanic and tectonic processes at spreading centers and transform faults. Ocean-bottom seismometers were deployed on the Gorda Rise to monitor microearthquake activity and correlate the earthquake activity with fault patterns mapped during an earlier deep-tow survey. These studies, as well as theoretical modeling of fault patterns, are still underway. During June, an ocean-bottom-seismometer microearthquake study of the Middle America Trench was conducted in conjunction with a deployment of land seismic stations by Mexican co-workers. Drs. Macdonald and Jordan are beginning the analysis of this experiment. On the same cruise, deep-tow studies of the East Pacific Rise and Tamayo transform fault were conducted that indicated unusual vertical, as well as horizontal, motions of the sea floor. These studies are being analyzed by Drs. Macdonald and Fred N. Spiess.

Dr. Jordan and graduate student Stuart A. Sipkin have been using digitally recorded seimic data from the High-Gain Long-Period (HGLP) and Seismic Research Observatory (SRO) global networks to investigate lateral variations in elastic and anelastic parameters existing in the upper mantle. Dr. Jordan has recently elucidated a method for retrieving lateral variations from low-frequency eigenspectra data. Working with Dr. Raymond P. Buland and Silver, he is attempting to apply this method to the very long-period data now available from Project IDA (International Deployment of Accelerometers).

On the analytical front, Dr. Orcutt and graduate student Jan D. Garmany are implementing the asymptotic propagator theory of Woodhouse in order to improve capabilities in the generation of synthetic seismograms. Spudich is making a detailed analysis of shear velocities in the oceanic crust and upper mantle, using hydrophone data of Drs. Russell W. Raitt and Shor, and Garmany has developed a spectral inversion technique for travel-time data.

Dr. Moore and Marvin D. Elston and Huang are deeply involved in the development of a next-generation, broadband microprocessor-based, four-component, digital, ocean-bottom seismograph that will allow studies of seismic surface waves and long-range recording of body waves from earthquakes, and thus add to the capabilities of the present instruments.

The principal research activity of Dr. Jacqueline Mammerickx is to define the broad lines of the morphology of the ocean floor in the Pacific. Underway bathymetric data are systematically collected by researchers aboard the major

Scripps vessels and processed and archived under the curatorship of Stuart M. Smith at the Geological Data Center.

Analyses of these bathymetric data have led to the establishment of a chart of the Pacific Ocean in 21 sheets published by the Institute of Marine Resources. A second edition of this chart has been started with the publication of *A Bathymetry of the East and Southeast Asian Seas,* in meters and in ten colors, in cooperation with Dr. Robert L. Fisher and Emmel and Smith.

Regional geomorphic studies were completed in the Caroline Basins and in the northwest Pacific, where a channel has been discovered defining the passage of the flow of a thermohaline current.

The study of currents in submarine canyons, under the direction of Dr. Francis P. Shepard, has led to the discovery of two more, slow turbidity currents. One of them was from a canyon off the Abra Delta, northwest Luzon, Philippines, and differed from earlier discoveries because it occurred without unusual swell or storm conditions, but was apparently related to floods that were carrying large quantities of sediment into the sea at the canyon head. The other occurrence was in a canyon on the north slope of Puerto Rico. Here the turbidity current appears also to have come directly after a period of high rainfall and flood conditions on the Rio de la Plata.

Dr. Shepard made a survey from aboard R/V *Thomas Washington* off the northwest coast of Luzon. This survey included seismic profiles and revealed the presence of a large fault trough that extends diagonally down the continental slope into the Manila Trench. This may be related to the great Philippine Fault that extends out to the sea south of the Abra Delta.

A joint survey conducted by Duke University, Durham, North Carolina; West Indies Laboratory, St. Croix; and Scripps was made in the area between the islands of St. Croix and St. Thomas in the Virgin Islands. Dr. Robert F. Dill, West Indies Laboratory, was aboard Duke University's R/V *Eastward* during this survey that showed the relief in this area for the first time. A deep trough occurs between the islands and is bordered by large fault scarps that are cut by a series of deep canyons on the north slope of St. Croix. Current-meter records in two of the canyons show considerable differences from those found in most other submarine canyons. Here records show slow currents with high-frequency direction reversals except in one record at 49 m that showed at 3 m above bottom almost continuous downcanyon currents with pulses up to 30 cm/sec. At 30 m above bottom the current was predominantly upcanyon, but showed only slow current of around 13 cm/sec.

Previously, Dr. Moore had made a deep dive into the rift valley southeast of San Clemente Island, California, and had found strong indications of exclusively upvalley currents. However, in 30-day records with current meters from this same rift valley, he found that upcurrents alternated up and down valley with the semidiurnal tidal frequency as in submarine canyons along the California coast at comparable depths.

Gerald G. Kuhn is continuing his studies of coastal changes in northern San Diego County. He has found that the east basin of San Elijo Lagoon has had serious siltation problems caused by surface runoff of recent hillside housing developments. Part of this coastal zone has been mapped geologically to define past and potential future problems.

In another part of the world, the features and history of North Africa (Gondwana), including progenitors of the Red Sea and Tethys, are the subject of a multidisciplinary study begun a year ago by Drs. Albert E. J. Engel and Celeste G. Engel and colleagues. Field studies are now being expanded into the Sudan and Saudi Arabia, with additional participants from the United States and Middle Eastern countries.

The oldest recognizable crustal-rock complex of the Egyptian region studied consists of remnants of oceanic basins and arc-like volcanic edifices, with their volcanogenic aprons of agglomerates, flows, and coarse-to-fine wacke sedi-

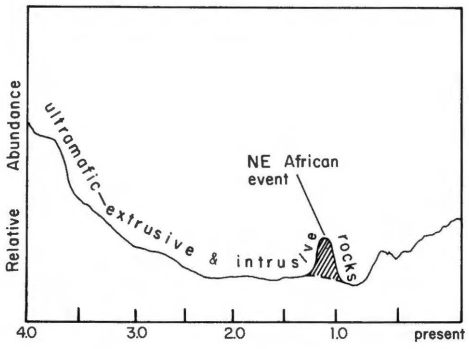


Photo of pillowed, tholeiitic, oceanic, basement basalt (above) in greenstone complex of Eastern Desert, Egypt. Crude estimates, plotted as function of time (below), show relative volumes of ultramafic lavas emplaced in earth's crust and preserved in geologic record. Dashed line at 1×10^9 years indicates crustal abundances independent of northeast African occurrences.

Drs. Albert E. J. Engel and Celeste Engel

ment fill. This oceanic complex of mid-Proterozoic age contains most elements of classic Archean greenstone belts (more than 2.5 billion years old), including a basement of pillowed tholeiitic basalt, ultramafic sills, thick sequences of immature wackes, intercalated iron formations, and the related volcanoclastic debris.

In Saudi Arabia, and presumably to the west, the oceanic basalts (a volcanic layer of Proterozoic sea floor) lie on a basement of ultramafics. The Drs. Engel find no other Proterozoic analog to this large, relict oceanic crust throughout the world. Hence, the widespread iron formations and ultramafics also are unique in the known Proterozoic history of the earth's crust.

The existing complex is refolded and refaulted, but its contiguous parts cover more than six-million-square kilometers of northeastern Africa. The volume of ultramafic lavas erupted is essentially a total melt of the mid-Proterozoic mantle, and exceeds 2×10^5 km^3. The entire "greenstone" complex is frozen in a sea of younger pink, alkali-rich, Pan-African granites (about 500 to 650 million years ago), which form most of the younger sialic crust in northeastern Africa.

Dr. Fisher, in collaboration with Dr. C. Engel and Dr. Carl E. Hedge, U.S. Geological Survey, continued laboratory study of the major element and rare-earth composition of igneous rocks of the lower crust recovered from the mid-ocean ridge system of the western Indian Ocean. Dr. Fisher and Dr. John G. Sclater, Massachusetts Institute of Technology (MIT), Cambridge, continued larger-scale, magnetic-topographic-tectonic evolution studies of the triple junction and Southwest Indian Ridge, a project in preparation for the spring 1978 joint field program that will include Scripps, MIT, Cambridge University, England, and the Institut de Physique du Globe, Saint-Maur-des-Fossés, France.

In shipborne field work, Dr. Fisher participated as a senior scientist in a six-week dredging, seismic-reflection, tectonic exploration of the Philippine, Palau, Yap, and Mariana trenches. The multinational cruise aboard the Soviet R/V *Dmitri Mendeleev* was part of "Project Ophiolites" of the International Geological Correlation Program; Dr. Fisher was aboard from Manila to Sydney. Rock sampling was carried out principally along profiles established on Scripps's 1962 Proa Expedition. Recovered were two-pyroxene gabbros, olivine gabbro, diabase, porphyritic basalts, amphibolites, and andesites from the Yap and Palau trenches' deep nearshore walls and, additionally, cumulate gabbros and peridotites and tectonized peridotites from the Mariana Trench south of Guam. Deep offshore walls of all four trenches yielded relatively fresh pillow basalts and diabase of the oceanic suite. Field trips at Yap Island and Salamaua, Northeast New Guinea, permitted comparison of these putative ophiolite suites of the deep trench walls and oceanic crust with well-studied exposures on land.

Photograph of first worm to be found in its burrow in a deep-ocean core. Worm was recovered in Pacific Ocean sediment by Dr. Wolfgang H. Berger's research group during Pleiades Expedition. Dr. Berger says these burrowing organisms mix upper layers of sediment and disturb "pages" of geologic history.

David L. Ripley

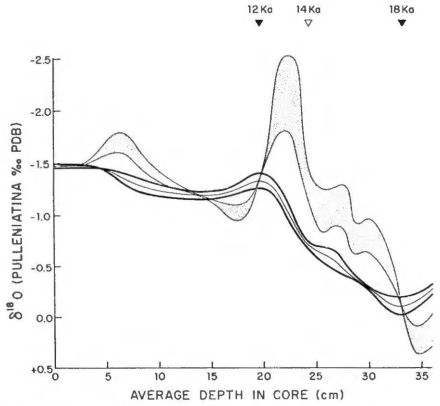


Chart indicates oxygen isotope composition of foraminiferans through the glacial-postglacial transition in the western equatorial Pacific. Heavy lines show average of values from four box cores each. Center line is average of the two heavy lines. Shaded region indicates possible original signal, assuming partial destruction of the record of benthic mixing, according to the Berger-Heath mixing model, with a mixed layer thickness between four and eight cm.

Dr. Wolfgang H. Berger *et al*

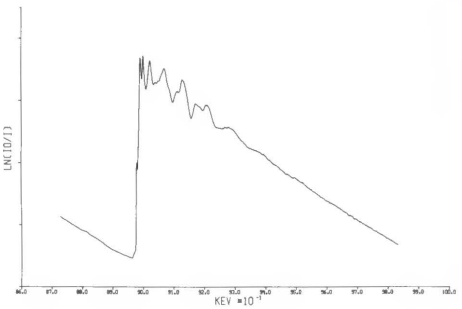
Dr. William R. Riedel and coworkers are exploring the application of computer-age technology to planktonic microfossils. Dr. Riedel, Annika Sanfilippo, and colleagues are cooperating on the computer storage of radiolarian descriptors and sketches as an alternative to Linnean names, and statistical manipulation of those data. Ichthyoliths, microscopic skeletal debris of fishes, are being used to determine ages of pelagic sediments lacking the more familiar planktonic microfossil groups. A summary of all information presently available on ichthyoliths is also being compiled. Dr. Riedel's group continues conventional stratigraphic and taxonomic work on radiolarians from the European Mesozoic and Deep Sea Drilling Project Cenozoic sequences.

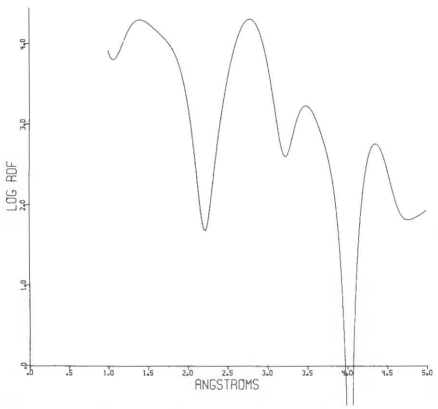
Studies on the late Mesozoic deep-sea sediments by Dr. Hans R. Thierstein are in progress and yielded some unexpected results. The sediment record from the North Atlantic reveals that the carbonate preservation line shoaled from a depth of about 4.5 km, 120 million years ago, to less than a 3-km depth 80 million years ago. A sudden deepening to more than 5 km is observed between 66 and 60 million years ago. Detailed, quantitative, taxonomic anal-

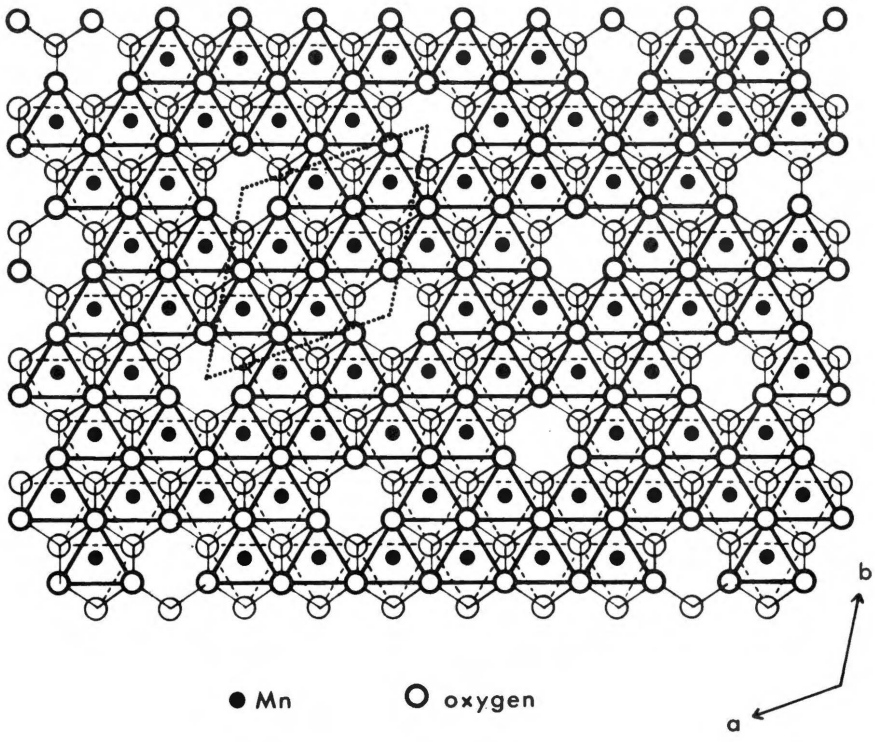
ysis of calcareous nanoplankton suggests that the extinction of the Cretaceous taxa was instantaneous. A catastrophic event, such as a solar flare or a supernova, rather than a slower climatic or paleobiogeographic change, appears to be the most likely cause for the well-documented extinctions of oceanic plankton, cephalopods, and dinosaurs at the Cretaceous/Tertiary boundary.

Graduate student Rachel M. Haymon is exploring the Mesozoic sedimentary record of various Deep Sea Drilling Project sites for clues of a possible ancient deep-water fractionation between the major ocean basins.

The deep-sea carbonate group, Drs. Wolfgang H. Berger, Edith S. Vincent, John S. Killingley, and Charles G. Adelseck and graduate students Richard F. Johnson, Larry A. Mayer, and Robert B. Dunbar, continued its work on the application of preservation stratigraphy and stable isotopes to sediment dynamics, and to paleoceanography. Most recently, attention focused on the period of transition from glacial to postglacial, a time of major disturbances in the physics and chemistry of the ocean. For a brief interval, 14,000 years ago, the world ocean became more saturated with calcium carbonate than it is now. This is reflected in a downward excursion of all levels of equal preservation of calcareous fossils. Shortly afterward, about 12,000 years ago, there was a major influx of glacial melt water, which apparently resulted in a considerable lowering of the salinity of the upper water layer. This is reflected in anomalously high $^{16}O/^{18}O$ ratios. If correct, there are important consequences for ocean mixing and the ocean-atmosphere interaction at the time.







These three figures illustrate graduate student Stephen E. Crane's application of X-ray absorption spectroscopy (XAS), a new, high-resolution technique, to the determination of the atomic positions of substituent elements such as copper, nickel, and cobalt in manganese-oxide crystal structures.

Top figure is the K X-ray absorption edge of metallic copper, showing pronounced absorptive fine structure. The sharp feature on the edge itself is a bound-state transition characteristic of elemental copper.

The middle figure shows the Fourier transform (or RDF — radial distribution function) of the fine structure of the absorption edge of copper ions incorporated in the structure of birnessite ($Na_4Mn_{14}O_{27}\bullet 9H_2O$), one of the characteristic manganese-oxide minerals found in deep-sea nodules. The RDF may be thought of as a (distorted) picture of the electron density as a function of distance from the absorbing atom. Positions of the peaks (after correction for quantum mechanical scattering effects) correspond to the locations of shells of neighboring atoms, and their heights are a measure of the number of atoms in each shell.

The bottom figure (courtesy of Dr. Roger G. Burns, Department of Earth and Planetary Sciences, Massachusetts Institute of Technology) shows the structure of birnessite that consists of sheets of edge-linked MnO_6 octahedra with regularly distributed vacancies. XAS measurements made it possible to determine, with unique accuracy, the position of copper ions in this structure. Analysis of the RDF in the middle diagram shows that the copper ions occupy positions immediately above the vacancies.

Stephen E. Crane

The work in Gustaf Arrhenius' group has included further study of the processes in the early solar system that relate to the formation of the ocean and atmosphere, and their interaction with the crust and interplanetary space.

In the course of a study of processes leading to large, nonequilibrium isotope fractionation in nature, the fractionation of nitrogen in reactions with oxygen at low kinetic temperature has been investigated in collaboration with Ray W. Fitzgerald, Stephen Markus, UC San Diego student, and Charles S. Simpson, UC San Diego graduate student. Reactions of this kind are important in the upper atmospheres of the planets and in interplanetary and interstellar space. They are also of interest in understanding the effects of nitrogen oxides on the ozone layer in earth's atmosphere. The fractionation of ^{15}N over ^{14}N is found to vary over a range that reaches 31 percent at 80°K.

A substantial effort in this group is devoted to the formation of transition element deposits on the sea floor, particularly in conjunction with the formation in the Equatorial Pacific of manganese nodules with extensive substitution of copper and nickel. Graduate student Stephen E. Crane has successfully applied a new, high-resolution technique for determination of the atomic position of substituting elements such as copper, nickel, and cobalt in the manganese-oxide crystal structures. This technique, known as extended X-ray absorption fine structure analysis, employs a high-power, X-ray beam from synchrotron radiation, and uses the linear accelerator at Stanford University, California, to excite individual species of atoms and to measure the backscattering of photoelectrons from neighboring atoms in the crystal lattice. Interatomic distances can, in this way, be determined with a precision 10 to 20 times higher than is possible with X-ray diffraction. At the same time, fine structure of the absorption edge reveals the valence state of the atoms in question.

As a contribution to the understanding of the complex phenomena that control the composition and distribution of manganese nodules, Jane Z. Frazer, Mary B. Fisk, and Donna L. Hawkins have continued to systematically collect and evaluate information on geological samples from the deep-sea environment. A study by Frazer, together with Dr. H. William Menard, on the basis of this material, demonstrated an inverse correlation between the density of coverage of nodules and the content of nickel and copper in the Pacific Ocean. A practical application of these studies is in a new evaluation of the total potential mine sites that shows the number to be considerably lower than many earlier estimates.

The pollution of coastal marine waters was the basis for many of the investigations carried out by Dr. Edward D. Goldberg and his associates, John J. Griffin, Minoru Koide, and Dr. Vernon F. Hodge.

The contamination of coastal zones is being measured through the use of sentinel organisms that accumulate pollutant materials in their bodies. Bivalves, such as mussels and oysters, have proved to be particularly appropriate recorders of the levels of petroleum, artificial radionuclides, and industrial chemicals, such as the polychlorinated biphenyls, insecticides, and heavy metals in the seawaters from which they were recovered. The gulf, east, and west coasts of the United States are being monitored by utilizing such organisms, and during 1976-1977, collections were made from more than 125 stations. Heavy metal pollution was especially evident in estuaries such as Narragansett Bay, Rhode Island, and San Francisco Bay, California, while the discharges from the manufacture of DDT could be measured in the bodies of the mussels collected in the Los Angeles harbor. The program is a cooperative venture among Scripps; Woods Hole Oceanographic Institution, Massachusetts; Moss Landing Marine Laboratory, California; University of Texas, Austin, and UC Berkeley.

A more detailed study of man's impact upon the coastline was made on the Savannah River Estuary, Georgia, in collaboration with scientists from the Skidaway Institute of Oceanography, Savannah, Georgia. Concern existed over the possible leakage of plutonium and other transuranic elements from the nuclear facilities located on rivers discharging into this region. Unexpectedly, much lower levels of plutonium were found in the sediments deposited over the last two decades than in the deposits from other coastal zones of the United States, indicating that there apparently has been effective management of radioactive wastes in this area.

The vaporization of metals from rocks at temperatures found at the earth's surface is being investigated by Drs. Georges Desaedeleer and Goldberg. Rock samples are irradiated in nuclear reactors such that many elements are made radioactive. Those that

Among geochronological studies carried out during the year were those on fission-track dating techniques. Accompanying light micrograph shows fission tracks in a crystal of zircon. Each track is about ten micrometers long. Visibility of tracks has been enhanced by etching process that increases diameter of each track about 100 angstroms to a micrometer or more. Each track records spontaneous fission of an atom of uranium 238; as much as 1,000 parts of U-238 per million are found in zircon.

Dr. J. Douglas Macdougall

volatilize are trapped and their radioactivity uniquely identifies their nature. The atmospheric contents of some heavy metals appear to result from such processes.

Dr. Devendra Lal's group collected gram quantities of marine suspended matter from the surface and deep waters of the Atlantic and the Pacific, using specially developed filter matrix and pumping systems. The mineralogical, chemical, and radiochemical composition of the particulate matter collected has provided valuable information on 1) distribution of particulate phases and its biogenic and terrestrial components in surface waters on a global scale; 2) regeneration rates of calcium carbonate and silica in deep waters and organic carbon in near-surface waters; 3) interelement associations in surface particles, and their alteration prior to burial in sediments, and 4) sinking velocities of particles and fluxes of radionuclides to ocean floor. Most of this work was carried out during the GEOSECS (Geochemical Ocean Sections Study) expeditions to the Atlantic and Pacific oceans.

During the past year Dr. J. Douglas Macdougall's group has carried out investigations of geochemical and nuclear processes in materials ranging from deep-sea manganese nodules to deep-space meteorites.

Using alpha-particle radiography, they have examined the distribution of alpha-emitting species in a large number of manganese nodules at very high resolution. These data are used to determine nodule accumulation rates, and to investigate in detail the nature of manganese nodule growth. Comparison of their growth-rate data with those determined by conventional radiochemical analyses of the same samples indicates excellent agreement. They have also used this new method successfully to determine the accumulation rates of deep-sea sediments.

They have completed an investigation of uranium contents and distribution in oceanic basalts, with emphasis on old samples recovered by the Deep Sea Drilling Project. Basalts altered by seafloor weathering have high uranium contents and were also found to be high in potassium. The ratio of potassium to uranium abundances indicates that basalt weathering may be the major oceanic sink for these two elements. As an offshoot of this study, they are currently analyzing the isotopic composition of uranium in weathered portions of basalts of known ages. This work, carried out in collaboration with Dr. Robert C. Finkel, may shed light on the time scale of the alteration processes.

An important new area of research that was initiated successfully this year is the use of the isotopic composition of the rare-earth element, neodymium, as a tracer for the sources of oceanic volcanic rocks. Samarium-147 decays with a long half-life ($\sim 10^{11}$ years) to neodymium-143, and the decay system provides valuable insight into fractionation processes affecting the earth's mantle. Even the relatively small amount of data collected during the past year has provided important constraints on the generation of oceanic basalts. This work, carried out in close collaboration with Dr. Gunter W. Lugmair, UC San Diego, will constitute a major portion of graduate student Richard W. Carlson's thesis.

In addition to the investigations described above, work continues on a number of other long-term projects: 1) Geochronologic studies using fission-track dating; 2) dating of local archeological sites by the fission-track method; 3) monitoring of soil radon for fluctuations associated with seismic activity (in collaboration with Dr. Harmon Craig), and 4) wide-ranging investigations of the origin and evolution of meteorites, particularly the carbonaceous chondrites (in collaboration with scientists at UC Los Angeles, University of Chicago, and Physical Research Laboratory, Ahmedabad, India).

The Isotope Laboratory research group (Drs. Craig, Ray F. Weiss, John E. Lupton, and Yu-chia Chung) continued its studies of mantle-crust-seawater interaction processes, and of GEOSECS expedition samples from the Pacific. The study of hydrothermal circulation in basalt at oceanic spreading centers, begun last year, was continued as a joint effort between the Isotope Laboratory and the Deep Tow research groups. On Pleiades Expedition in 1976, the existence of hydrothermal plumes had been demonstrated for the first time; Drs. Weiss and Peter F. Lonsdale were able to collect samples of these plumes using the Isotope Laboratory's "sampling sled" attached to the Deep Tow's "fish." Helium isotope measurements, made by Dr. Lupton, showed large He^3 enrichments, which proved that these waters had circulated extensively through fresh basalts. During June, Dr. Lupton used the "sampling sled" with the Deep Tow group on F Drake 77 Expedition, to survey the East Pacific Rise at 21°N. Small, but reproducible, temperature spikes were measured with the GEOSECS Operations Group's CTD (Chemical/Temperature/Depth) instrumentation. Ten of these spikes were sampled for helium and Mn measurements that will establish the degree of interaction of water and basalt.

Drs. Lupton and Craig completed helium isotope measurements on geothermal water and gas samples collected in the Ethiopian Rift Valley as part of a study sponsored by the United Nations Development Program and the Ethiopian Government. The He^3/He^4 ratio in all of those Ethiopian samples was distinctly above the atmospheric ratio, thus indicating the presence of the "mantle" helium component also found in oceanic basalts and in volcanic areas. Three of those samples showed He^3/He^4 ratios about 15 times atmospheric, a value distinctly higher than the average for helium in ocean-ridge basalts. This very high He^3/He^4 ratio, which has also been found in gas from Kilauea fumarole, Hawaii, may represent a deep-mantle or "hot-spot" helium component distinct from the upper-mantle helium found trapped in ridge-crest basalts.

The main effort of Dr. Chung was to measure the Ra-226 and Pb-210 content of Pacific Ocean waters collected during the Pacific GEOSECS Expedition, and to study their geographic variations in relation to large-scale oceanic mixing and circulation. For the Ra-226 program, he has completed the E-W section along 30°N in the North Pacific and part of N-S section along 180° longitude. In addition to a large excess of "primary" Ra-226 found in the northeast Pacific deep water, there is a pronounced mid-depth maximum of radium in the central Pacific induced by the presence of low-Ra bottom water flowing north below high-Ra deep water flowing south. For the Pb-210 program, he has completed all the soluble and particulate profiles in the North Pacific. A distinctive mid-depth maximum of soluble Pb-210 is also observed. The radioactive disequilibrium found between Ra-226 and its daughter Pb-210 indicates a rapid removal of lead from the water column. Measurements of Pb-210 in both the soluble and particulate phases suggest that the particulate matter is an effective scavenger for lead in the oceans.

Other activities of this group consisted primarily in preparation for the

forthcoming Indian Ocean GEOSECS Expedition that will take place on R/V *Melville* from December 1977 through April 1978. Drs. Craig and Chung will direct the first leg of the expedition, beginning in Port Said, Egypt, and Drs. Weiss and Lupton will lead leg 2.

Beginning in February 1977, Dr. Weiss assumed responsibility for development of the deep-sea geochemical instrumentation that is to form the core of the multiinstitutional Manganese Nodule Program (MANOP) sponsored by the National Science Foundation. The principal goal of this program is the identification of the processes that govern the formation of deep-sea ferromanganese nodules and the determination of their chemical composition. Toward this end, Dr. Weiss's group has begun to design and construct two, new, free-vehicle "bottom landers" that will be deployed on the sea floor for periods of up to several months and will carry out *in situ* experiments designed to study the exchange of transition metals and other chemical species between the bottom water, sediments, and nodules. Bottom chambers carried by the landers will be used to study these processes both in a passive sense and by the use of added radioisotopic and chemical tracers or "spikes." The landers will collect a time-series of water samples from each chamber, and will recover a core sample of the nodules and sediment exposed to each chamber experiment. Present plans call for the deployment of the landers in five Pacific pelagic sediment zones, with detailed site surveys to be carried out by the Deep Tow instrument system.

Dr. Weiss has also continued his research on trace gases in the sea, with special emphasis on the transport of nitrous oxide between the ocean and the atmosphere. This trace gas is the principal natural modulator of the earth's ozone layer, which provides major protection against ultraviolet radiation. Measurements on samples collected during Pleiades Expedition in the eastern tropical Pacific have shown the upwelling that dominates this region carries a substantial flux of nitrous oxide into the atmosphere.

Marine Biology Research Division

Investigations in the Marine Biology Research Division embrace experimental and 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.

Most of the division is now housed in the newly completed Marine Biology Building adjacent to the new Scripps Library. Occupancy began in March 1977. This building, 3,600 m^2 of assignable space, is intended to house 35 academic staff, 55 students, and support staff. In addition to offices and laboratories, the building includes one large, multipurpose, experimental aquarium, three, small, aquarium rooms, all supplied with ambient and chilled seawater, an X-ray room, and several controlled environment rooms. An electron microscope, with attachments for scanning and X-ray fluorescence, will shortly be installed. The building contains two small conference rooms and a large, separate, conference center joined to the building.

Studies in Dr. Andrew A. Benson's laboratory have revealed structures, mechanisms of biosynthesis, digestion, and physical properties of marine lipids. Lipids, fats and oils are the major medium for energy transfer in marine food chains, and are also important to man. Collaborative studies between Drs. Judd C. Nevenzel and Felipe Fernandez provide new insight into the role of wax ester, a major energy storage lipid in copepods. The study allows correlation of energy storage with metabolic and reproductive requirements.

The role of the most powerful of the calcium-regulating hormones, the calcitonin produced by salmon, was investigated during a six-week study in British Columbia waters aboard R/V *Severiana*, a private vessel. In Dr. Benson's studies with Dr. Gérard G. Milhaud, Faculty of Medicine, University of Paris, and Dr. St.-Antoine C. Rankin, University College of North Wales, the salmon's calcitonin was found active in regulating calcium influx into the gill. The relation of this process to that of the mammalian hormone in regulating bone-calcium loss became clear, thus opening the way for improved understanding of the function of this important hormone, clinically important in treatment of osteoporosis. Another marine model for human disorder was discovered when Dr. Grant Bartlett, Laboratory of Comparative Biochemistry, San Diego, found in the chimaerid ratfish, a first marine example of the sickle-cell human hereditary disorder.

In a U.S. Bureau of Land Management-funded study of petroleum hydrocarbon accumulation in benthic and intertidal organisms, organic pollutants such as DDE, dioctyl phthalate, and PCBs have been analyzed and identified, in addition to the hydrocarbons from natural and industrial sources. Pristane, squalene, and a novel branched alkane were the dominant natural hydrocarbons. Biological fates of selected hydrocarbons are under study.

Transport of carbon dioxide in biological systems is being studied by Dr. Theodore Enns. Recent measurements have determined diffusing capacity of carbon dioxide in dog lungs, thus providing a good basis for evaluating the factors controlling excretion of carbon dioxide from the blood of humans. These studies are continuing in collaboration with Dr. Esther P. Hill, UC San Diego School of Medicine. Experiments have shown that the enzyme carbonic anhydrase plays a significant role in carbon dioxide excretion by mammalian lungs.

As a necessary part of the carbon dioxide transport studies, the kinetics of carbonic anhydrase-carbon dioxide reactions have been determined for several forms of the enzyme extracted from animal and plant tissues. A significant finding in these kinetic studies was that none of the tested forms of carbonic anhydrase showed any marked change in activity over a wide physiological range of pH and carbon dioxide concentration.

Dr. Denis L. Fox continued his researches and writing on the character of animal biochromes and the comparative metabolism of ingested carotenoids. During the year, he and Donald W. Wilkie completed a joint study on carotenoid metabolism in the plumose anemone *Metridium senile fimbriatum.* Further joint studies continue on carotenoid biochemistry in marine animals.

In July 1976, Dr. Elizabeth Kampa Boden introduced to her investigation of the vertical distribution and movements of mesopelagic animals, the acoustically telemetered controls for opening and closing of, and monitoring of the environment with, the rectangular mid-water trawl. The trawl goes

down closed; opening and subsequent closing are effected by casting off bridles attached to the acoustic control device. The unique feature of the trawl itself is that the lower edge of the mesh is shorter than the upper, such that during towing a 90° angle exists between the two, and animals with spiny or setose appendages are not snagged in the ripples that prevail in nets with equal upper and lower dimensions.

Dr. Boden has used the basic trawl with satisfactory results from a Leavitt opening/closing device. The introduction of the acoustic control allows the operator to know the absolute depth and time of opening and closing. Sixteen hauls were accomplished on the shake-down cruise, without a single failure, and those operating the controls soon learned to keep the trawl within 1 or 2 m during tows at as many as 650 m deep, simply by altering ship speed and the meters of wire paid out.

The trawl was used again, most successfully, on Leg 2 of the Farewell to Aggie cruise aboard R/V *Alexander Agassiz* in August and September. The primary intent of this effort was to confirm or refute 1974 observations of the differences in photoenvironment in the North Equatorial Current, South Equatorial Current, and Equatorial Countercurrent. The 1976 observations were made some 60° to the west of those taken near the Galâpagos Islands in 1974, but the photoenvironments from the surface to depths as great as 500 m demonstrated a marked similarity in each of the currents. At each of the stations, the triumph of fishing a 12-kHz sonic-scattering layer during its upward migration during twilight was achieved. These migrating communities contained sternoptychids, myctophids, and gonostomatids in sufficient abundance to account for the low-frequency scattering. The predominant members of the biomass were, however, crustaceans.

In 1976, Dr. Ralph A. Lewin spent three months as the first Senior Research Fellow at the Roche Research Institute of Marine Pharmacology, in Dee Why, Australia, where he initiated a program of research on the production of potentially antibiotic substances in fermentation cultures of various marine algae. He spent the remainder of his sabbatical leave at the Botany School, Oxford University, England, where he studied infestation of the common duckweed, *Lemna,* by a green intercellular alga, *Chlorochytium,* both particularly abundant as a consequence of the long, dry, summer in England.

In 1977, he organized a small expedition to Singapore to study the fine structure, photosynthetic activity, and nucleic acid composition of the paradoxical alga *Prochloron.* Although new species of algae are being described daily, the discovery and description of a new algal division is something that happens only a few times in a century. Dr. Lewin claims to have established a new group (the Prochlorophyta) at this level, based on certain unique combinations of characters in algal cells (*Prochloron* spp.) associated with didemnids (colonial ascidians). These algae have the typical pigments of the Chlorophyta (chlorophylls a and b, etc.), and these as in other green algae, are borne in paired sac-like organelles called thylakoids. However, unlike all other known green algae, the cells of *Prochloron* lack a membrane-limited nucleus and have therefore to be considered as prokaryotic. Dr. Lewin has proposed that they be classified in a new division of algae, the Prochlorophyta, a status equivalent to the Cyanophyta (blue-green algae), which they resemble in certain other respects (chemical composition of the cell walls, etc.).

In collaboration with Lily Rüdenberg, Farlow Herbarium, Harvard University, Cambridge, Massachusetts, Dr. Joan G. Stewart has found that 13 species of Californian red algae in the family Delesseriaceae have multinucleate cells, the nuclear numbers being primarily species-specific, but in some species, dependent on the position of the cells in the thalli. This suggests that the regulation of nuclear division in such algae differs in certain respects from that of plants with the more usual condition of uninucleate cells, or coenocytes, in which the numbers of nuclei are apparently indeterminate. In addition, Dr. Stewart has been studying the systematics, morphology, and changes in seasonal abundance of some dominant intertidal "turf" algae on four reefs in San Diego County.

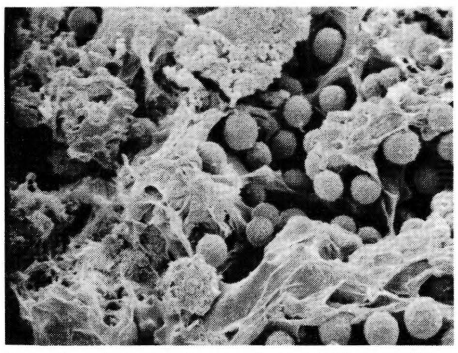
Dr. Kenneth H. Nealson has been studying various aspects of the symbiotic relationship between luminous bacteria and marine luminous fishes. Dr. Nealson has shown that the luminous bacteria possess a unique mechanism called autoinduction, by which they control the synthesis of the luminous system. Edward G. Ruby, graduate student, has shown that the symbiotic luminous bacteria excrete organic acids and has proposed a model of symbiosis. Ruby has also verified that luminous symbioses are quite species specific. The tryptophan operon of a luminous bacterium has been mapped and the enzymes characterized.

In another effort, marine bacteria capable of manganese oxidation are being studied. Taxonomic characterizations have shown that ten bacterial groups can be distinguished. Investigations of the physiology and biochemistry of these bacteria indicate that they can use the energy of manganese oxidation for growth and CO_2 fixation.

Dr. Richard H. Rosenblatt initiated an investigation of genetic differentiation and evolutionary rates of New World tropical marine fishes. Until the late Pliocene, a seaway across Central America allowed genetic interchange between marine fish populations of the Caribbean and the eastern tropical Pacific. The populations were then isolated by the closure of the seaway. One consequence of this isolation was morphological differentiation and speciation; there are now a number of species pairs, one form in either ocean, differing only slightly in morphology.

Morphological differentiation is an indirect indication of genetic divergence. A direct measure may be obtained through the techniques of biochemical genetics. Frozen samples have now been obtained by field work in the Caribbean and the eastern Pacific. The samples are now being processed by the technique of starch-gel electrophoresis, to determine differences in mobility of enzymes. The results should give an indication of the amount of genetic differentiation that has occurred in a number of fish groups as a result of geographic isolation.

Dr. Kenneth L. Smith's research over



Scanning electron micrograph (1,050X magnification) of critical-point dried material by Ellen L. Flentye and Dr. Lanna Cheng shows cells of prochlorophyte Prochloron ***on colonial tunicate (Didemnum sp.).*** **Ellen L. Flentye and Dr. Lanna Cheng**

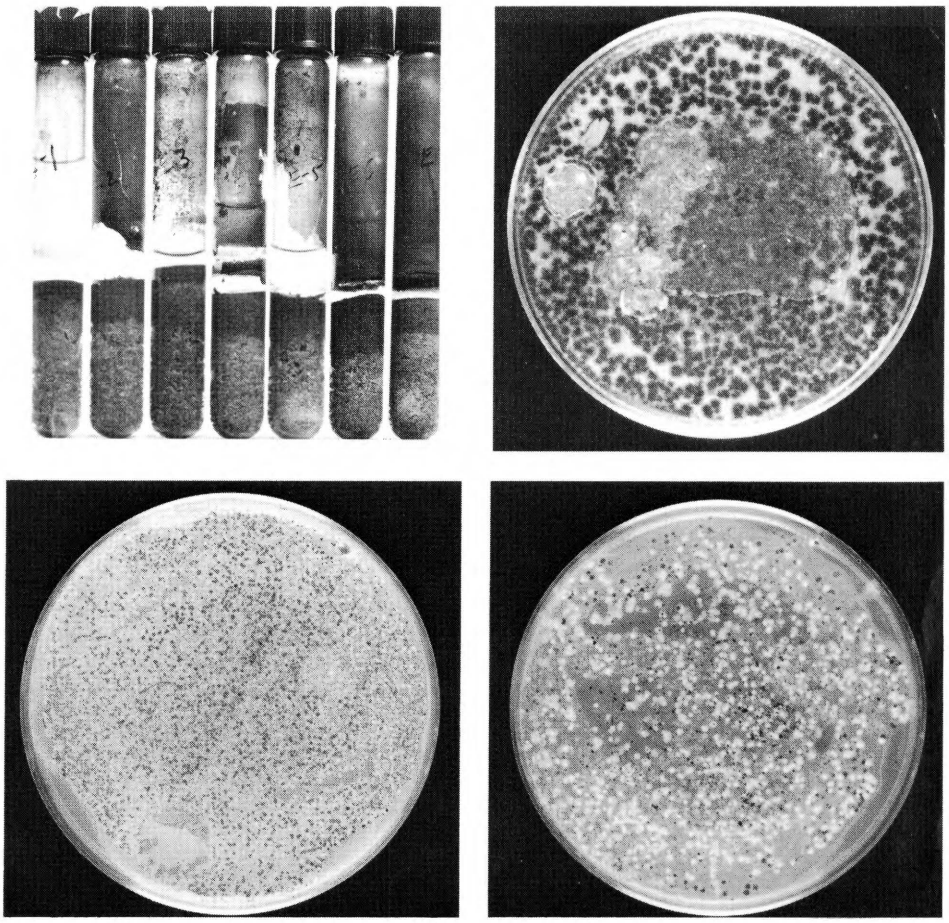
the past year has dealt with the *in situ* measurement of metabolism of deep-sea benthic communities and benthopelagic animals, by using recently designed, free-vehicle equipment and submersible operated instruments. Rates of oxygen consumption and nutrient flux (NH_4^+, NO_3^-, NO_2^-, and PO_4^{+3}) of deep-sea sediments in the northwestern Atlantic are significantly lower than rates in shallow water at comparable temperatures.

Measurement of the metabolism of a rattail, *Nematonurus armatus*, was made *in situ* at 2,750 m in the northwestern Atlantic. Oxygen consumption and NH_4-urea excretion rates were significantly lower than those of phylogenetically related shallow-water fishes measured at comparable temperature and activity rates.

Dr. Smith's group examined shelf sediments, beneath the Peru upwelling system, where dissolved oxygen is limiting. High rates of denitrification were found with rapid uptake of NO_3^- by the sediments and release of NH_4^+ and probably N_2.

Development of equipment for measuring the *in situ* metabolism of deep-sea animals continues. A slurp gun respirometer and epibenthic fauna respirometer, for measuring the metabolism of mid-water animals and large epibenthic animals, respectively, have been constructed and await testing this summer.

Adaptations by enzyme systems to the varied physical and chemical stresses characteristic of the marine environment were the major focus of work in the laboratory of Dr. George N. Somero. The studies of graduate student Joseph F. Siebenaller revealed that highly similar, congeneric fish species that occur at different depths in the ocean have markedly different forms of the same types of enzymes, with the enzymes of deeper-occurring species having greatly reduced sensitivities to hydrostatic pressure. These findings provide at least a partial molecular explanation for species zonation patterns over depth in the oceans. Studies by Paul H. Yancey, graduate student, demonstrated that the enzymes of elasmobranch fishes (sharks, skates, and rays), which accumulate urea to concentrations of 300-400 mM, are urea-requiring proteins, unlike the homologous proteins of non-urea accumulators. Work by R. David Bowlus, graduate student, on the molecular basis of free amino-acid accumulation by marine invertebrates revealed that the free amino acids that are used in highest concentration for osmotic regulation are solutes that do not perturb enzyme structure and function. Unlike high salt concentrations, high levels of free amino acids permit optimal enzyme function in a concentrated intracellular solution. In addition to these comparative studies, work was continued on the roles that change in enzyme hydration play 1) in enhancing the catalytic potential of enzymes, and 2) in effecting salt activation and inhibition of catalysis.



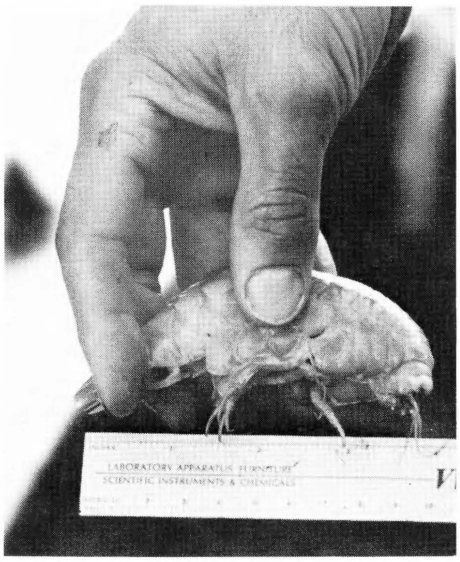
When marine sediment samples are incubated in the presence of manganese, the growth of organisms that oxidize and precipitate manganese is favored. Upper left picture shows a series of bacterial enrichment cultures. The other three pictures demonstrate growth of bacteria that have been inoculated into agar plates from three different enrichment tubes. Dark colonies are manganese-precipitating organisms; they have subsequently been isolated and studied in pure culture. Dr. Kenneth H. Nealson sees the goal of such studies to be the elucidation of the bacterial contribution to geochemical cycling of manganese in the ocean.

Dr. Benjamin E. Volcani and his associates continued the exploration of the biochemistry of silicon (Si) in cell metabolism.

Having previously found Si-granules in the mitochondria of diatoms and rat tissue, Dr. Charles W. Mehard undertook to see what effect calcium and/or phosphate might have on *in vitro* granule-formation by liver mitochondria. Granules of differing morphologies, number, and size were formed in the presence of Si, Si + P, and Si + P + Ca. This demonstrates that the granules are not adventitious, and the results are relevant to theories as to mitochondrial function and biological mineralization.

Dr. Roger N. Johnson found that silicic acid ($^{31}Si\,[OH]_4$) uptake in liver mitochondria is limited and independent of mitochondrial energy status. It consists of two components: the greater part is bound, probably to protein; the other remains free within the mitochondrial matrix. The relation of these results to the Si-granules is being studied.

Silicate minerals (as asbestos fibers) are strongly implicated in lung cancer. Dr. Walter J. Desmond is studying the contribution of Si to this toxicity in cell cultures. With Dr. Scott Linthicum, he has demonstrated that polymeric + monomeric silicic acid produces instantaneous damage to cell surface membranes, followed by aggregation of the damaged material, endocytosis. Many of the treated cells become binucleated or multinucleated, thus



Scientist holds one of the larger amphipods trapped with a free-vehicle baited device during R/V* Thomas Washington's *work in the central North Pacific on Indopac Expedition. The specimen,* Eurythenes *sp., measured about 10 cm in length, and was one of many deep-sea scavengers collected by Dr. Robert R. Hessler's group.

George D. Wilson

indicating inhibition of cytokinesis; treatment induces varying degrees of binucleation in most cell lines and of primary tissues. The mechanism of this induction is being studied.

Thomas W. Okita, graduate student, showed that the diatom, *Cylindrotheca fusiformis*, required Si for the synthesis of two nuclear DNA polymerase activities, and for a DNA-binding protein; Si represses the synthesis of at least 15 other DNA-binding proteins. Hence, it appears that Si participates in regulating gene activity in the diatom. He also found that Si increases polypeptide turnover and changes in labeling rates (^{35}S) when Si is withheld.

Dr. Claude E. ZoBell has observed that certain mixed cultures of anaerobic bacteria enriched from marine mud samples produce gas from various substrates at deep-sea pressures. The gas usually consists mainly of carbon dioxide, methane, and hydrogen, with lesser quantities of hydrogen sulfide and nitrogen. The composition of the gas seems to depend upon the physiological types of bacteria present and the chemical composition of the medium in which they are grown. For example, in nutrient media containing sulfate and sulfate-reducing bacteria, the latter may oxidize hydrogen, thereby resulting in a decrease in hydrogen and an increase in hydrogen sulfide:

$$SO_4^{=} + 5H_2 \rightarrow H_2S + 4\,H_2O$$

The rate of gas production has been found to be retarded somewhat by pressures as low as 200 atm. At 500 atm, gas production was only about one-fourth as rapid as at one atm and barely discernible at 1,000 atm. Since all of the gases produced go into solution at such pressures, it was necessary to "boil off" the dissolved gases in the terminal analytical process.

Marine Life Research Group

Five members of the Marine Life Research Group (MLRG) collaborated on a study of "Ocean Circulation and Marine Life." Joseph L. Reid and Drs. Edward Brinton, Abraham Fleminger, Elizabeth L. Venrick, and John A. McGowan presented the results of this study to the Joint Oceanographic Assembly at Edinburgh, Scotland, in September 1976.

They discussed the geostrophic nature of the gross patterns of ocean circulation, with the wind-driven convergences within the anticyclonic gyres and the divergences within the cyclonic gyres, along the equator and the eastern boundaries. Because of the gyres' several climates and differences in vertical circulation, they contain different sets of nutrient and temperature characteristics, and these provide separate oceanic habitats. The principal cyclonic gyres are in the subarctic and subantarctic latitudes and have equatorward extensions along the eastern boundaries. They are cold, high in nutrients, and undergo large seasonal changes; a relatively small number of species are indigenous to these gyres, but the biomass is relatively large. The principal anticyclonic gyres are in the subtropical zones, are warm and low in nutrients, with less seasonal variations than at higher latitudes; a larger number of species are indigenous to these gyres, but the biomass is small. The subequatorial zone contains a series of alternate eastward and westward flows, with associated ridging in thermocline depth. It is the warmest of the zones at the surface, but is colder beneath the upper layer than are the anticyclonic gyres. It also contains a large number of species and a large biomass, but there is substantial east-west variation: some species are confined to the east.

On board R/V* Thomas Washington, *Bryan R. Burnett and Julie A. Michaelsen screen sediment from the deep central North Pacific Ocean in search of macrofauna during Indopac Expedition. Specimens are being used for extensive studies of deep-sea ecology.

Dr. Elizabeth L. Venrick

While these general patterns are observed in all oceans, there are notable differences. The tropical gyre of the North Atlantic, which is the warmest of the oceans, extends into higher latitudes; some species can extend as far as Novaya Zemblya, islands off the coast of USSR (75°N), at least in summer.

Phytoplankton species appear to have patterns somewhat different from those of the zooplankton. The subarctic and subantarctic gyres contain some bipolar species of zooplankton, but few, if any, of phytoplankton, and the subequatorial zone appears to contain no endemic species of phytoplankton. Phytoplankton species tend to be more widespread and less environmentally specialized than zooplankton species.

In the past year, Drs. Fleminger and Kuni P. Hulsemann have continued their studies on evolution and biogeography of planktonic copepods. The questions pursued were geographical range, taxonomic divergence, geographical variation, and speciation among certain species groups in the calanoid copepod families, Calanidae and Pontellidae.

One study concerned the geographical range and taxonomic divergence of the three members of the *Calanus fin-*

marchicus species group in the North Atlantic. The known distribution of *Calanus helgolandicus* in the North Atlantic Drift is difficult to explain in the absence of a reproductively active population inhabiting continental waters off eastern North America. Zooplankton samples collected between Cape Hatteras and the New York Bight, off the east coast of the United States, brought out evidence that this population does, in fact, exist. Sexual activity in these stocks of *C. helgolandicus* was indicated. The new records provide a likely origin for the presence of the species in the vicinity of the Labrador Grand Banks as well as in the North Atlantic Drift. *C. finmarchicus*, similarly sexually active, was found to be sympatric with *C. helgolandicus* in the samples that were taken from a region contiguous with the southernmost known distribution of *C. glacialis*. Strikingly different patterns in the distribution of integumental organs (pore signature patterns) among the three species were found in the urosome; this and the successively overlapping ranges suggest that divergence from the generic pattern of integumental organ distribution has been a product of selection against hybridizing among the three species. If this is the case, the reproductive range of *C. helgolandicus* has overlapped with those of *C. finmarchicus* and *C. glacialis* for appreciable periods in the history of the three species.

Drs. Fleminger and Hulsemann noticed a trend in the variation of a pore signature pattern of the North Atlantic *C. helgolandicus* populations from west to east. With additional material from the entire range of the species, including the Mediterranean and the Black seas, it was possible to document gradual and statistically significant differences between certain populations. Differences between the Mediterranean and the virtually isolated Black Sea populations led to the elevation of the latter from subspecies to species rank.

In contrast to the North Atlantic, the North Pacific supports a greater number of species of the genus *Calanus*. Studies are complete on the distribution and character divergence of the populations of the *C. pacificus* species group, including the description of a new species from the Gulf of Panama.

Four newly described species of Pontellidae, assignable to the *Labidocera jollae* species group, a uniquely American radiation of coastal planktonic copepods, have been discovered in the western tropical North Atlantic-Caribbean region. These species are related to and apparently derived from the American west coast lineage of the *Labidocera jollae* group. The new species bring the number of coastal water species of *Labidocera* indigenous to the western tropical North Atlantic to nine.

Dr. McGowan and his students have been studying the structure and function of the central anticyclonic gyre plankton community of the North Pacific. A great constancy of spatial pattern in the vertical dimension has been determined. There is also a very constant species rank order of abundance. Both of these aspects of structure show little variability within seasons or between years. Thus the community appears to be very well regulated and to consist of several groupings of species that are frequent parts of each other's habitat over time and space. Since the spatial relationships of competitors and predators and their prey affect the outcome of the interactions between them, the determination of spatial pattern is an important aspect of the study of function.

The primary productivity of the gyre shows no significant seasonal change; however, one year (1969) it averaged twice that of previous or subsequent years. This change was associated with a persistent and large-scale negative temperature anomaly over most of the eastern sector of the North Pacific. The enhanced productivity was caused by an increased rate of mixing upward of deeper, cooler, high-nutrient water. It is hypothesized that this was caused by turbulence associated with unusual internal wave activity that year. The empirical evidence tends to support this view.

A comparison of the spatial and temporal coherence of community structure of the gyre and California Current showed the latter to have much less constancy. This may mean that the two areas tend to have different processes regulating community structure and perhaps function.

Research has continued by Dr. Venrick on the vertical stratification and seasonal cycle of phytoplankton in the Central Pacific Ocean. Analysis of chlorophyll and productivity data collected along 35°N on Indopac Expedition I, April 1976, indicates that the typical central gyre structure predominated from the western edge of the California Current to approximately 158°W. Farther west, the chlorophyll distribution altered markedly with the disappearance of the characteristic subsurface maximum layer and appearance of high, but variable, near-surface values. Productivity also showed a marked increase on the western side of the ocean. On a gross scale these features corresponded well with the general hydrographic properties and it is hoped that a more detailed analysis will elucidate the nature of the relationship.

Dr. Brinton and Margaret D. Knight are continuing to investigate euphausiid crustaceans, "krill" inhabiting the California Current. The principal species appear to differ in their responses to seasonal and annual variation in the environment. Population characteristics such as larval development, rate of growth, survivorship, and biotic production are being studied by using the extensive plankton collections obtained by California Cooperative Oceanic Fisheries Investigation (CalCOFI) cruises since 1949. In conjunction with Dr. Christopher P. Mathews, Escuela Superiór de Ciencias Marinas, Baja California, production estimates have been obtained for *Euphausia pacifica*'s southern California population, the first such estimates to be obtained for an oceanic zooplankter. Consistent differences appear to exist between the sizes and frequency distributions of the two locally predominant species, *E. pacifica* and *Nematoscelis difficilis*. In *N. difficilis* the frequency of different-sized animals remains nearly constant through adolescence and mid-adulthood, apparently because mortality is balanced by decreasing growth rate, whereas in *E. pacifica*, survivorship tends to diminish exponentially with increasing body length throughout the life span. Graduate student Tarsicio Antezana is analyzing samples representing euphausiid populations of the Peru-Chile Current, waters that are geographically analogous to those off California.

The study of larval development of the Euphausiacea has contributed information on the systematics, distribution, and evolution of the species identified. The larvae of *Euphausia fallax* have been described and illustrated, thus completing the investigation of the three members of the *Euphausia gibboides* species group. Growth and development of the larvae of the group were compared and larval characters were distinguished that appear to be specific to the species group within the genus and that suggest a close relationship of two of the species within the

group. Larvae of *Euphausia eximia,* a species of the southern portion of the California Current and the eastern tropical Pacific, are now being studied.

Among the most primitive of the mid-water fishes, the family Searsidae is being studied by Tetsuo Matsui. Little is known of its life history and the taxonomy is in an unsatisfactory state. Studies of the material of searsids, collected during Scripps expeditions and from other institutions, on the taxonomy and distributions of the species are nearly completed. These studies reveal that the species generally occur in highly productive areas and that the more primitive members of the family are mostly the mesopelagic and the advanced bathypelagic. Three new species, one occurring off California, have been described. Larval stages of two of the five species occurring off California have been identified and are being examined.

Data for 21 physical, chemical, and biological variables from 216 stations in the California Current for 1969 have been analyzed by technicians using oblique factor analysis and factor score mapping in an attempt to expose the multivariate structure of this oceanic ecosystem.

Three physical regimes have been described numerically. These are mixing processes (low temperature, low salinity, and high oxygen), upwelling processes (low temperature and high salinity), and thermal stratification (high temperature, high salinity, and shallow mixed layer) processes. Phytoplankton nutrient chemicals (PO_4^{+3}, NO_3^{-}, and SiO_3^{+2}) tend to co-occur with mixing and upwelling processes. Nitrite tends to be associated with thermally stratified waters during the summer. High chlorophyll abundances are associated with mixing and upwelling regimes, but first-feeding and very young anchovy larvae are associated with upwelled and stratified waters. Anchovy larvae 2-5 mm and 8-25 mm tend to have mutually exclusive distributions.

The annual cycle for 1969 began in winter with domination by mixing processes, was later (March-June) dominated by upwelling processes, became stratified in late summer, and commenced to become mixed once again in the autumn.

These characteristics of the California Current revealed through numerical analysis are understandable within the context of historic concepts of physical, chemical, and biological dynamics and distributions. The data that were employed were generally available. Greater definition of the ecosystem may result as previously untapped sources of historic data are analyzed and become available. Further analyses may provide predictive capacity for fishery stock management.

The geological-biological laboratory within the MLRG program continues to participate in a varied set of investigations. Studies on the varved sediments of the Santa Barbara Basin in southern California have resulted in a considerable list of chemical contaminants and biological factors that exhibit a decipherable historical pattern, and added to that list is the parameter charcoal. MLRG scientists in collaboration with A. Roger Byrne, UC Berkeley, have shown that a correlation exists between local fire frequency and the incidence of specific charcoal fragments in the year-by-year sediment record. Extension of this relationship to sediment depths representing pre-Columbian times provides a means of estimating natural fire frequency, a question of considerable environmental and economic consequence.

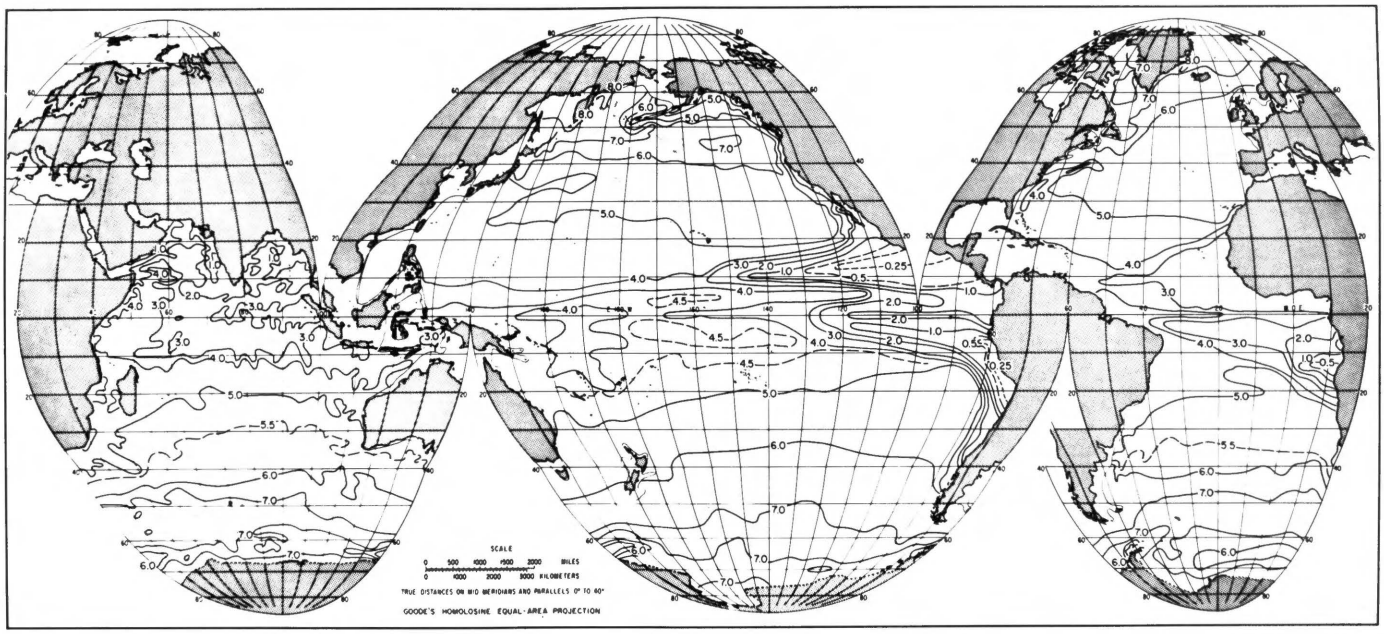
Work has continued on the anaerobic sediment record off Peru to compare the fluctuation of the fish populations with those off California. Dating of these sediments by the Pb-210 method has been successfully carried out by Minoru Koide, and micropaleontologic investigation is presently underway. Initial indications suggest substantial fluctuations of the input of anchoveta scales to the sediments. Recently, on a cruise off Peru conducted by Dr. Kenneth L. Smith, Andrew Soutar was able to collect and, for the first time, successfully transport a large volume frozen box core back to the laboratory.

Many of the activities of the group have been directed to the acquisition of sampling and analytic equipment. Dr. Stanley A. Kling, in cooperation with Dr. Elizabeth Kampa Boden, has adapted an acoustically monitored opening-closing net for operation with fine mesh nets (62μm) in the deep ocean. This gear was recently tested on R/V *Thomas Washington.* Development of a micro-computer-controlled densitometer system continued and is being used to scan and analyze X rays of varied sediments. This approach is especially valuable when looking at the longer 3,000-4,000-year record available in the cores collected using the Scripps-"Big Bertha" piston corer.

Soutar has participated extensively in the collection of high quality surface and subsurface sediment over the entire Southern California Bight. The system devised for these collections emphasizes multicorer operations and a minimum of contamination. The majority of samples are forwarded to various analytical laboratories throughout many universities and the state for trace metals, high molecular-weight hydrocarbons, microfauna, and sediment analysis. However, Scripps technicians are involved in the analysis and processing of certain cores for age-dating to update the historic patterns of trace-metal contaminations off southern California. As an extension to the benthic program, a study of in-the-water collection of sediment by means of geochemically clean, particle interceptor traps is being prepared.

Growing awareness of the pollution of the ocean surface by oil and other insoluble flotsam has recently focused attention on a hitherto neglected biotope, the sea-air interface, and the unusual animals that are specialized to live there, the pleuston. The first comprehensive review of this in English was recently compiled by Dr. Lanna Cheng. All Scripps research vessels now regularly collect pleuston samples, which are later analyzed on campus. However, one of the easiest ways of sampling inshore pleuston, after periods of onshore winds, is beachcombing. Analysis of populations of two species of pleustonic barnacles washed ashore near Scripps during one such period, enabled Dr. Cheng to draw conclusions about the settling habits and biology of these animals.

Dr. Cheng's main scientific interest remains the study of marine insects that, despite persistently repeated statements to the contrary, exist in a wide variety of families, forms, and habitats. The most nautical of all insects is *Halobates.* Dr. Cheng's studies were designed primarily to interact with parallel investigations of temperature, current, and wind variations at the ocean surface. Recently, however, this research has led somewhat unexpectedly into the field of heavy-metal pollution, since the discovery that in certain areas *Halobates* concentrates the toxic cation, Cd, in amounts that may exceed 100μg/g dry weight. Correlation of the data with similar information now being obtained for sea birds at the Monks Wood Experimental Station, England, may ultimately provide information on the pathway of such heavy metals through



Distribution of dissolved oxygen (ml/l) at 100 m in world ocean, as indicated by study of ocean circulation and marine life by Joseph L. Reid and Drs. Edward Brinton, Abraham Fleminger, Elizabeth L. Venrick, and John A. McGowan.

Goode's Projection: Reprinted by permission of University of Chicago; copyright, Department of Geography, University of Chicago.

marine food chains.

An investigation of the southwestern part of the Atlantic Ocean has been carried out by Reid and Dr. William C. Patzert and Dr. Worth D. Nowlin, Texas A&M University, College Station. The waters found within this area extend into it as separate layers with markedly different characteristics. Along the western boundary the deeper waters, derived from the North Atlantic, are warm, highly saline, oxygen-rich, and nutrient-poor. This North Atlantic Deep Water (NADW) lies within the density range of the Circumpolar Water (CPW) from the south, which is cooler, lower in salinity, very low in oxygen, and very high in nutrients. Where the NADW and CPW meet in the southwestern Atlantic, the NADW separates the CPW into two layers above and below the NADW, each less saline, richer in nutrients, and lower in oxygen than the NADW.

These layers appear to be separated vertically by density gradients that tend to be sharper at the interface than in the layers themselves. These maxima in stability, which result from the interleaving of water masses from different sources, extend over hundreds of kilometers.

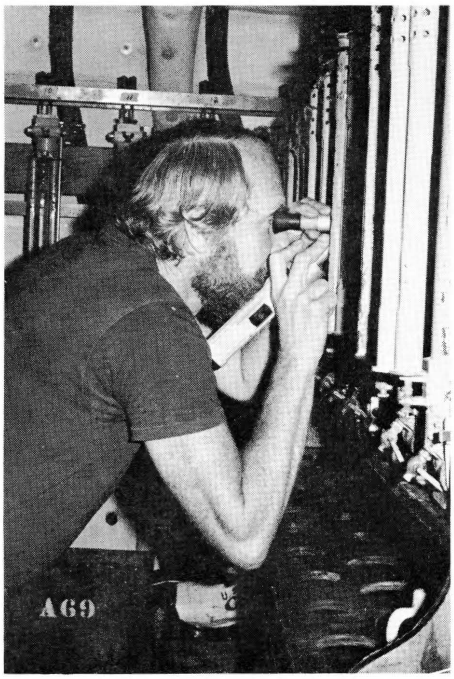
Within the Argentine Basin the circulation of all except the abyssal layer appears to be anticyclonic and so tightly compressed against the western boundary that equatorward flow is observed just offshore of the poleward flow at the boundary. Waters from the north (within the Brazil Current near the surface and from the North Atlantic at greater depths) flow southward along the western boundary and turn eastward near 40°S, part returning around the anticyclonic gyre and part joining the Antarctic Circumpolar Current. Likewise the Circumpolar Waters, which have entered from the Pacific, flow northward along the western boundary to about 40°S and then turn eastward, both above and below the NADW. The abyssal waters are derived from the Weddell Sea. Within the Argentine Basin they flow northward along the western boundary, turn eastward south of the Rio Grande Rise, and then southward on the western flank of the Mid-Atlantic Ridge; the abyssal flow is cyclonic beneath the anticyclonic upper circulation.

Parallel with the work reported at Edinburgh, Reid completed a study of the effect of world ocean circulation upon the transmission of sound. The resulting temperature structure largely defines the speed of sound, and the circulation specifies the habitats of animals that cause scattering of sound.

Reid and Arnold W. Mantyla have continued their research on the deep circulation of the world oceans, and during last year's Indopac Expedition, collected data in and around the Philippine Sea and the Mariana Trench and the Challenger Deep, the deepest known basin in the world. During this cruise it was found that the bottom water enters the Philippine Sea from the south by way of the Mariana Trench, the depression between Mariana Islands and the Kyushu-Palau Ridge, and then spreads west and south. Analysis of the bottom-water samples in the Mariana Trench and Challenger Deep, to nearly 11 km, indicates that the oxygen, salinity, and nutrients were identical to the measurements made at 5 to 7 km. Calculations of the potential temperature at 11 km supported the newer adiabatic lapse-rate equations over the older expression of Helland-Hansen.

In the field of instrumentation, the electronics group under Meredith H. Sessions has installed five coastal wave-monitoring stations at Imperial Beach, Ocean Beach, Scripps Pier, Oceanside Pier, and Port Hueneme, all in southern California. These stations were maintained throughout the year on an operational basis with monthly data reports issued to users shortly after the end of each month. Preliminary work has been completed to convert the stations to digital data transmissions.

Also completed was testing of a prototype, dual-propeller, ocean-current meter designed to measure near-surface currents in the presence of wave noise. For the first time a suitable sensor is now available for shallow water or near-surface currents that overcomes the inherent problems associated with older-style rotor current meters. These units are now in use by the Shore Processes



H. Ross Kay reads thermometers in Nansen bottles for marine phytoplankton studies in the central North Pacific Ocean conducted by Dr. Elizabeth L. Venrick during Indopac Expedition.

Dr. Elizabeth L. Venrick

Study Group for measuring shallow water currents in the nearshore environments. Additionally, a vector measuring and computing version is nearing completion for use in near-surface currents in the open ocean.

The electronics group has continued monthly airborne expendable bathythermograph (AXBT) flights in the eastern Pacific; round trip between Adak, Alaska, and Hawaii through April 1977. The techniques developed from this multi-year program will be used to monitor temperature sections across the equator in the eastern Pacific in the winter of 1977. In connection with this equatorial monitoring program, current meters and mooring systems have been developed to withstand the very rigorous environment of the equatorial currents. These units will be deployed during the same period as the AXBT flights.

The group also supported several other groups with the design and fabrication of digital recording current meters for submarine canyon work and time release mechanisms for biological collections in the trenches of the western Pacific Ocean.

Daniel M. Brown has continued the development of new instruments for use in the deep ocean. The new lightweight camera, which can take a series of pictures of the bottom or of the operation of instruments on the bottom, has been successfully used. Also, a new magnetic release system and a pressure fish trap were used in the Challenger Deep. Several patent applications are pending for new plankton and fish nets used in oceanographic research.

Marine Physical Laboratory

The Marine Physical Laboratory's growth since 1946 has been characterized by expanding interests and development of new technology in support of ocean research. From its inception, with primary interest in underwater sound, it has moved into all aspects of seagoing marine geophysics and into sonar and ocean technology. This growth in areas of interest has been paralleled by development of such unique research facilities as 1) FLIP (Floating Instrument Platform), a manned spar buoy research platform; 2) a deeply towed sea-floor survey system; 3) ORB (Oceanographic Research Buoy), the general-purpose research barge used to support studies of reverberation, and 4) ADA (Advanced Detection Array), the newest of the special platforms. Sponsorship and principal support has remained with the Office of Naval Research.

The laboratory's thirtieth anniversary was celebrated in November with the formal dedication of the new Ocean Engineering Support Facility at Point Loma. The new facility houses Marine Physical Laboratory's (MPL) engineering activities, machine shops, and electronic equipment construction areas.

Principal speaker at the dedication ceremonies was the Chief of Naval Research, Rear Admiral Robert K. Geiger, USN. In addition to recognizing the long history of MPL accomplishments, he presented the Navy Distinguished Civilian Service Award to MPL's deputy director, Dr. Victor C. Anderson.

Dr. Anderson's current research is focused on studies of the fine-scale spatial structure of ambient noise in the ocean. This required the development of a major new research tool, ADA. This array, with its 720 hydrophones and associated signal-processing electronics, was completed during the year by the engineering group under Daniel K. Gibson and began its first seagoing operations. The array structure is 21 m long and 8.8 m wide and is towed in tandem with the research barge ORB. ADA is attached to ORB by an umbilical cable that serves as part of the towing and mooring system as well as the electric power and telemetry link. The plane of the array is horizontal when towed, but on station it is rolled horizontally 90° onto its side and winched under by ORB to its submerged operating position. The seagoing work has involved establishing the handling and performance characteristics of the array platform, and training the operating crew for research sea trips. These operations were conducted in waters off San Diego. All test objectives have been achieved and array calibration has begun in preparation for the initial investigations of the details of ambient noise structure of the ocean.

The Deep Tow Group, under the direction of Dr. Fred N. Spiess, took part in two cruises on R/V *Melville*: Pleiades Expedition, Leg 4, in the fall of 1976 and F Drake 77 Expedition, Leg 7, in the spring of 1977. During the first of these cruises, part of the National Science Foundation Manganese Nodule Research Program, the deep-tow precision sounders, side-looking sonars, and cameras were used to delineate fine-scale topography and nodule distributions and to guide precision sampling for related chemical studies. On the second expedition leg, led jointly by Dr. Spiess and Dr. Kenneth C. Macdonald, the tectonic and hydrothermal processes on the East Pacific Rise crest at 21°N and the nearby Tamayo transform fault were studied. Data from earlier work by Dr. Peter F. Lonsdale and others, showed significant hydrothermal activity at the Galápagos spreading center, and was synthesized to provide base information for the Woods Hole Oceanographic Institution (WHOI), Massachusetts, successful *Alvin* submersible geochemical and geological observation program at that location. Graduate student Kathleen Crane was aboard *Alvin* during these dives. Robert C. Tyce, UC San Diego graduate student, completed his thesis based primarily on development and use of the deep-tow, 4-kHz, high-resolution, sub-bottom profiling system. He found substantially lower sound attenuation (factor of five) in carbonate sediments compared with more common clays, and an indication that there may be fine-scale (10-20 cm) layering observable through acoustic interference effects in some sedimentary structures. This work was extended by graduate student Larry A. Mayer as part of the Pleiades Leg 4 work. Dr. Carl D. Lowenstein, the deep tow engineering group under

Dr. Fred N. Spiess cuts cake during celebration of thirtieth anniversary of Marine Physical Laboratory (MPL) as Director Nierenberg (right) and Rear Adm. Robert K. Geiger, USN, Chief of Naval Research, watch. During the observance, Admiral Geiger presented the Navy's highest civilian service award, the "Distinguished Public Service Award," to Dr. Victor C. Anderson, MPL deputy director, "in appreciation of distinguished public service to the Department of the Navy." Dr. Spiess, who also is an associate director of Scripps, has served as MPL director since 1958.

Decoration photo by Bob Redding, courtesy of Union-Tribune Publishing Co.

Dwight E. Boegeman, and the equipment development shop under William L. Davy have continued to provide specialized technology transfer and assistance to other groups working in this field, and received a special commendation from the U.S. Naval Oceanographic Office in recognition of this support.

During the past year, marine geophysical studies of the structure and tectonics of the "collision zones" of southeast Asia have involved many MPL staff members. The program is intended to elucidate the processes that take place and the structures that result when two or more lithospheric plates are in collision. This has been a multiinstitutional, multinational effort, much of which has been part of the SEATAR (Studies of East Asia Tectonics and Resources) Program of IDOE (the International Decade of Ocean Exploration), CCOP (Co-ordinating Committee for Offshore Prospecting), and IOC (Intergovernmental Oceanographic Commission).

In July, on Leg 5 of Indopac Expedition, Dr. George G. Shor, Jr., led a study of structure in the Mariana Island Arc and the Philippine Sea, which was carried out in cooperation with Dr. Richard S. Lu, National Taiwan University, using R/Vs *Thomas Washington* and *Chiu Lien.* Results of this study indicate that the inter-arc basins of the eastern Philippine Sea are characterized by a thick volcanic layer, in contrast to the western Philippine Sea that has an anomalously thin crustal section. These data are being used to choose Deep Sea Drilling Project/International Phase of Ocean Drilling drill sites in the Philippine Sea. Graduate student Dale Bibee is also using these data for his thesis program on the nature of the crust in marginal seas. While conducting a seismic refraction station using the multi-hydrophone linear array, during the course of this multinational study, a previously unreported major deep, the 7,100-m Parece Vela Rift was detected.

On Leg 8 of Indopac Expedition, MPL scientists were back aboard *Thomas Washington* for a joint study with scientists aboard WHOI's *Atlantis II.* They studied the structure of the Banda Sea and the Sahul Shelf off northern Australia. Research involved standard seismic refraction, reflection, heat flow, gravity, magnetics, and coring. Among results of this joint study are the discoveries that the continental crust extends all the way from Australia to the bot-

tom of the deep Timor, Tanimbar, and Aru troughs, and that a possible small spreading center exists in the central portion of the Banda Sea.

Dr. Russell W. Raitt and others rejoined *Thomas Washington* in January for Leg 10 of Indopac. They worked with Dr. Eli A. Silver, UC Santa Cruz, on studies of structure in the Molucca Sea and used moored recording/telemetering seismic buoys. Graduate student Robert M. Keickhefer and Dr. Lawrence A. Lawver continued on Leg 11 for work in the Andaman Sea and carried out heat-flow studies and seismic refraction work with moored buoys. Paul O'Neill was sent to Burma to work with the staff of the Myanma Oil Corporation and to record offshore shots from *Thomas Washington* on land seismic equipment set up on the Irrawaddy Delta. Work with the multichannel reflection system and moored seismic buoys was continued on Leg 12 off the west coast of Sumatra. On Leg 13, under the direction of Drs. Shor and Joseph R. Curray, in cooperation with Indonesian research vessel *Sumudera*, work was carried out on two-ship refraction experiments using the multielement linear array for detailed refraction recording.

Studies during both Legs 12 and 13 were involved with the tectonic properties related to subduction and deformation along an arc-trench wall. The Nias-Sumatra region was a good location, because it is one of the few places where the trench wall contains basins large enough to probe. The Banda Sea program was ended during Leg 14 when additional underway geophysical studies were completed.

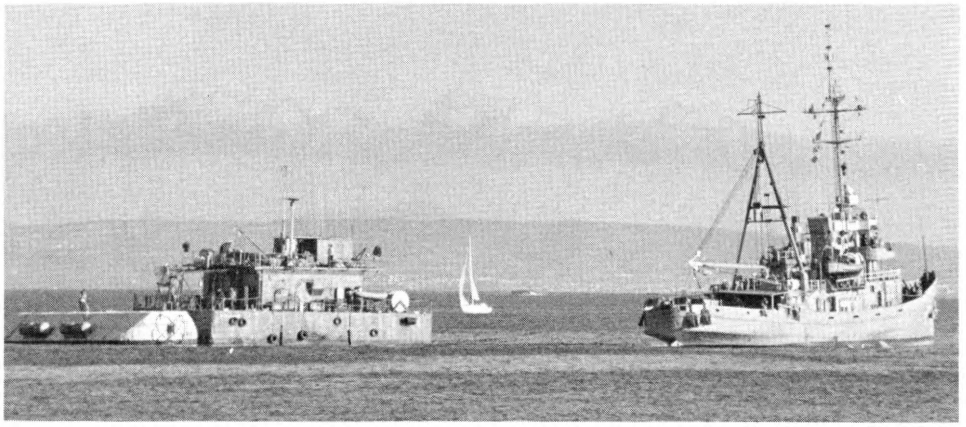
Humberto S. Carvalho, Federal University of Bahia, Brazil, and Victor Vacquier discovered high terrestrial heat flow behind the subduction zone of the Indonesian island arc, from analysis of oil field data in central Sumatra.

Dr. Frederick H. Fisher is studying multipath arrivals of CW acoustic signals at two frequencies, separating individual paths by their vertical angles of arrival. For this study he used a 532-m vertical array suspended from R/P FLIP at the deep, sound-channel axis. For a shallow source there appear to be only two principal arrivals at a range of ~322 km over most of the region between the seventh and eighth convergence zone, with the energy concentrated in sharply defined vertical angles (spread less than 1/2°).

In his studies of pressure-dependent, chemical equilibria, Dr. Fisher finds from a combination of his data on electrical conductance for single salts and the acoustic data of G. Kurtze and K. Tamm on $MgSO_4 - NaCl$ mixtures, that significant ion-pairing occurs for $MgCl^+$ ions.

A new equation for sound absorption in seawater has been developed, based on earlier acoustic absorption work on boric acid and magnesium sulfate. A reanalysis of the pressure dependence of absorption in $MgSO_4$ solutions and pure water provides a closer fit to the observed pressure dependence of absorption in the ocean than predicted from the widely used equation of M. Schulkin and H. W. Marsh. On the basis of the equation, there appears to be some evidence for the existence of another chemical relaxation process in the ocean at 3 kHz, which was reported at the Acoustical Society of America meeting in June 1977.

The first, major, data-collection cruise utilizing a multichannel Doppler sonar system was carried out by Dr. Robert Pinkel, using a converted 87.5-kHz transducer originally developed by Dr. Fisher. The Doppler sonar system was mounted on FLIP so that the beam was directed downward at an 8° angle to the horizontal. Analysis of the observed water velocity fluctuations as a function of depth showed a spectrum falling inversely as the frequency in the mixed layer (indicating turbulent motion) and inversely as the square of the frequency below (typical of a mid-water internal wave field). Also apparent was a high-frequency peak followed by a sharp cutoff at the Väisälä frequency. With these indications of successful operation, design work was initiated by William Whitney on a new transducer, which should assure greater operating range

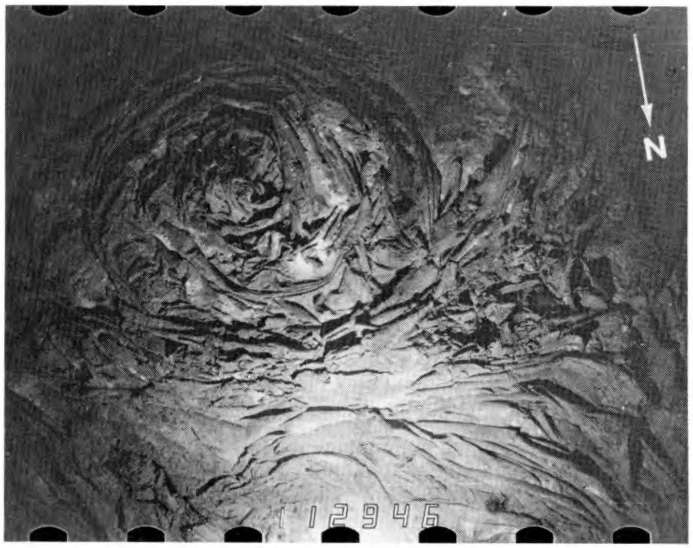


View of research platform ORB being towed to sea by USS Takelma *(ATF-113) for ocean noise studies, with Marine Physical Laboratory-developed submersible acoustic array ADA (far left) in tow.*

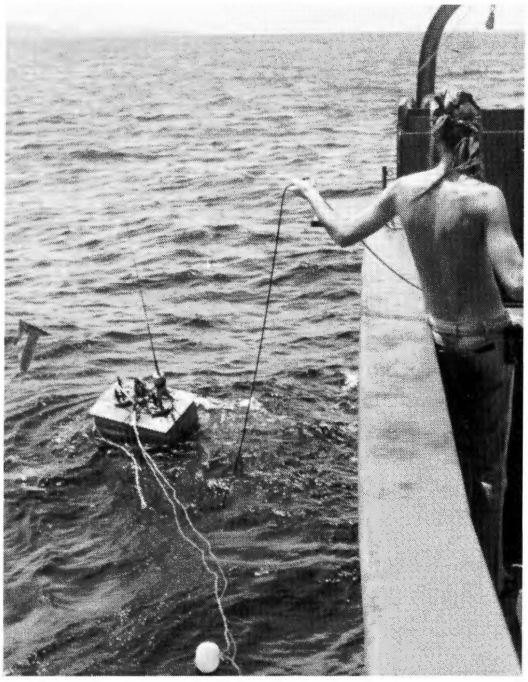
Philip H. Rapp

William R. Sessions, H. Wayne Wardlow, and Robert E. Bishop (from left), of Marine Physical Laboratory, mount doppler sonar on rotator base near bottom of R/P FLIP.

Marine Physical Laboratory



Upper of two photos taken by Marine Physical Laboratory's Deep Tow electronic instrumentation at 2,500-m depth near Galápagos Rift shows 4-m-diameter, right-handed coil in a region of ropy pahoehoe. Lower photo shows three such coils in same area. Arrows are one m in length.



Paul O'Neill launches recording/telemetering buoy unit from R/V Thomas Washington *for seismic refraction studies on Leg 10 of Indopac Expedition, in Molucca Sea. The inexpensive buoy units record hydrophone and clock signals on an internal cassette recorder, and also telemeter signals back to the ship up to ranges of 75 km. They replace earlier, less-reliable, balloon-telemetry systems.*

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and provide the first step toward a multiple-beam system.

Dr. G. Thomas Kaye participated in the same cruises and used his 6-m-diameter acoustic array mounted on the stern of FLIP to observe the variations in sound energy scattered from horizontally disposed reflecting surfaces in the ocean volume. Another aspect of the study of reverberation in the ocean was pursued by Brett Castile, UC San Diego graduate student, who used ORB moored at sea off the San Diego coast. A platform containing several, high-frequency, acoustic transducers was suspended from ORB, which provided a stable base for measurement of the reflections from the minute scatterers in the adjacent volume of water.

Dr. Gerald B. Morris has continued intensive analysis of acoustic data taken on previous FLIP cruises to study the propagation characteristics of East Pacific Ocean basins. He used the vertical line array suspended from FLIP while it was moored in the deep ocean. Dr. Morris has also participated in the laboratory's effort in applying acoustic techniques to the problems of undersea pipeline laying and repair, with sponsorship of Shell Oil Company.

Neurobiology Unit

As part of the newly created Marine Biomedical Program, the Neurobiology Unit brings together an interest in problems of animals in the sea and problems relevant to the basic medical science. A central theme is how higher invertebrates and lower vertebrates sense their environment and their position in it, process the information, and govern behavior.

Graduate student Jeffrey T. Corwin, UC San Diego School of Medicine, and Dr. Theodore H. Bullock studied the physiology of sound perception in advanced carcharhinid sharks. They used the method of computer averaging of electrical responses in the brain, recorded from electrodes implanted through the cartilage. This permitted mapping auditory regions in the hindbrain, midbrain, and forebrain as well as characterizing the most effective sounds, the recovery properties, masking, and the like. It also allowed experiments indicating the reception is not due to lateral-line sense organs but to the inner ear, with the principal port-of-sound entry being the mid-dorsal soft area called the parietal fossa. Several arguments point to the responsible part of the inner ear being the macula neglecta. Corwin has shown that this is the first vertebrate sensory-hair-cell population that maintains its proliferative ability postnatally; he has described the development, maturation, and senility of these sensitive mechanoreceptors by scanning electron microscopy and radioautography.

Electroreception both in electric fishes and in nonelectric fishes, especially sharks and catfish, continues to

Mounted on bottom of R/P FLIP is Marine Physical Laboratory's acoustic scattering array (SCAR).
Marine Physical Laboratory

occupy several laboratories. Dr. Walter F. Heiligenberg's comparative studies of electrolocation and jamming avoidance behavior in African and South American electric fish revealed differences that are a consequence of their independent, though convergent, evolution. Most strikingly, African species appear to identify feedback from their own electric activity by "gating" electroreceptive input by a central pacemaker, command-related signal linked to their own electric activity. South American species seems to lack this mechanism and appears to identify feedback by the activity of high threshold receptors, commonly responding only at the relatively high intensities of the animal's own electric field.

Eric I. Knudsen, graduate student, UC San Diego School of Medicine, distinguished separate parts of the midbrain in catfish that analyze sensory input from electroreceptors, acoustic receptors, and common, lateral-line sense organs. He found topographic segregation in the electroreceptive area with respect to part of the body, as well as to orientation of the most effective electric dipole and, in an orthogonal axis, with respect to the most effective frequency of alternation of the electric field. Terry A. Viancour, graduate student, UC San Diego School of Medicine, was able to uncover a basic cellular property of the sensory cells that explains the tuning of the high-frequency-sensitive electroreceptors in certain gymnotoids. He believes this finding is relevant to a modern theory of the "second filter" in hearing. Other aspects of the sensory and brain processing mechanisms have been studied by Drs. Albert S. Feng, Rocco A. Bombardieri, and Bullock.

Dr. Robert C. Eaton and collaborators completed projects on high-speed photography of the startle responses of 13 species of fish and on electrical recording as well as microscopic anatomy applied to the embryonic and larval development of the Mauthner cell system. These giant cells are already receiving sensory inputs, integrating them, and commanding the startle response only 40 hours after fertilization of the egg in *Brachydanio rerio,* the zebra fish. Collaborating with Dr. Henri Korn, Paris, France, Dr. Eaton has parallel studies under way on the tench *(Tinca tinca).* Dr. Charles Kimmel, University of Oregon, Eugene, and Dr. Eaton used gamma rays to cause lesions on zebra fish embryos; and some embryos with only one Mauthner cell show that this neuron mediates directional responses to local tactile-vibrational stimuli.

Dr. Lisbeth Francis, UC San Diego, continued her analysis of the aggressive behavior between colonies of gregarious sea anemones and the differences between the clonal and the solitary forms of the same species.

Dr. Jean K. Moore studied the nervous tissue of the lowest living vertebrate, the hagfish, using electron microscopy to search for any signs of the myelin sheathing that covers many nerve fibers in all higher groups. A major evolutionary step within the vertebrates, the invention of myelinated axons, by the ancestors of modern elasmobranchs, may thus be witnessed.

Graduate student David D. Jensen, UC San Diego School of Medicine, has been studying mechanisms of the spontaneous brain repair that occurs after a unilateral lesion of the organs of equilibrium (vestibular compensation) in mammals. Spinal somatosensory input was shown to affect the expression of acute postural asymmetry and its compensation in a variety of ways. He demonstrated new postural reflex relations and the spinal funiculi involved in the maintenance of compensatory postural symmetry, as well as evidence for neuronal plasticity in the compensation. Spinal input facilitates a greater fraction of the spontaneous neuronal activity in the descending vestibular nucleus of compensated animals than it does in normal animals.

Together with graduate student Jannon L. Fuchs, UC San Diego School of Medicine, Dr. James T. Enright has been involved in an experimental program to investigate the role of the pineal organ in the circadian wake-sleep rhythm of the house finch. This gland is not essential to the rhythms of certain mammals (for example, hamster) or lizards, but its removal from the sparrow leads to paradoxical results: an inability to show free-running rhythms under constant conditions, but retention of the ability to be synchronized by light and dark cycles. Results from the house finch study are similar to those in the sparrow; the pineal is clearly a part of the "clockworks," which cannot be replaced by continued, tonic dosage of its primary hormone, melatonin. Further experiments are planned to evaluate whether its role is that of a primary pacemaker, or a linkage element for a pacemaker located elsewhere.

Ocean Research Division

Ocean Research Division (ORD) is a broadly interdisciplinary division that consists of individual investigators as well as a number of research units. This report covers the research of individuals in biology, marine chemistry and geochemistry, geophysics, and physical oceanography during fiscal 1976-1977. It also describes the work of the Climate Research Group, Geochemical Ocean

Sections Study (GEOSECS), North Pacific Experiment (NORPAX), Shore Processes Study Group, and the Mt. Soledad Radioisotope Laboratory.

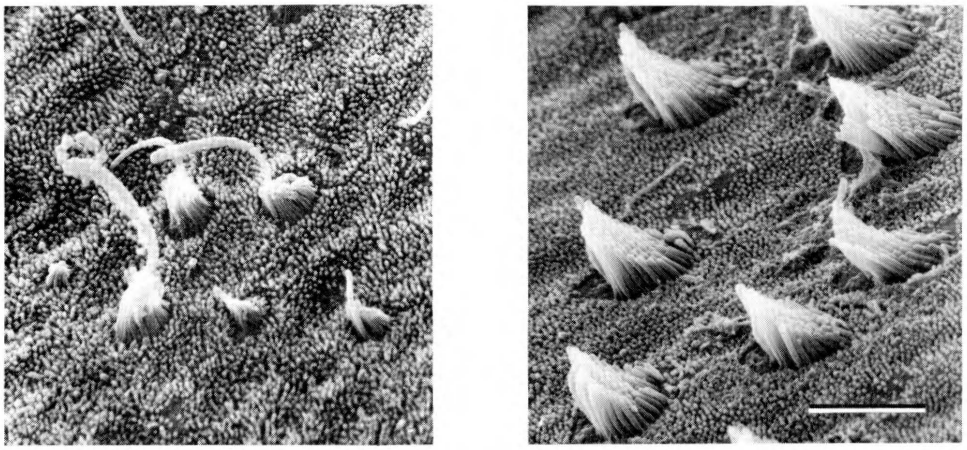
Dr. Charles D. Keeling and coworkers have continued their measurements of atmospheric CO_2. They now have a twenty-year record at Mauna Loa, Hawaii, and the South Pole, and shorter records at other locations. The data reveal a persistent CO_2 increase that is attributed to the combustion of the fossil fuels, coal, petroleum, and natural gas. A National Academy of Sciences panel, chaired by Dr. Roger R. Revelle, studied these data and concluded that continued combustion of fossil fuels may produce serious and long-lasting changes in world climate if the rise in CO_2 continues. The panel report includes Drs. Keeling and Robert B. Bacastow's geochemical model that predicts atmospheric CO_2 levels several times the current level during the next few hundred years, with a consequent rise in air temperature of up to 7°C.

To obtain a better understanding of CO_2 equilibria between air and seawater, a preliminary series of measurements of the partial pressure of CO_2 in equilibrium with seawater has been made. It is possible to determine the second dissociation constant for carbonic acid to high accuracy over a wide range of salinities and temperatures.

Dr. Tsaihwa J. Chow has initiated a new project concerning the marine chemistry of barium. In dealing with basalts, Dr. Chow found that barium is an "incompatible" element with strong affinities for melt phase and cannot readily enter into the predominant basaltic mineral phases; therefore, barium can be used as a discriminant between magma sources and also provide an indicator for a suite of rocks believed to be related by fractional crystallization. With the cooperation of Geological Research Division scientists, Dr. Chow has examined the barium content of various marine basalts from Lau Basin, East Pacific Rise, Mariana Trough and Mariana Islands, and Isla Tortuga.

Dr. Chow also studied the distribution of barium in soft tissues and in calcareous skeletons of marine invertebrates in relation to their environmental factors and carbonate mineralogy.

With U.S. Bureau of Land Management support, Dr. Chow studied the occurrence of selected trace metals, which may be introduced to coastal environments from offshore drillings, in marine sediments of the Southern California Bight that encompasses the shoreline, offshore islands, and benthic habitats from Point Conception to the United States-Mexican border. Areas adjacent to present or proposed oil and gas development leases were emphasized in the study. The Bureau of Land Management with these chemical data and other oceanographic information, can now better predict the impact of Outer Continental Shelf oil drillings and formulate a long-term monitoring program in subsequent efforts on these critical zones.



As a graduate student in the UC San Diego School of Medicine, Jeffrey T. Corwin has been investigating the ear of a shark in his research in Scripps's Neurobiology Unit. These scanning electron micrographs depict tufts of cilia, each one representing one sensory cell of the type believed to be the detectors of acoustic stimuli in the macula neglecta. Tufts from cells at the margin of the macula (left) are believed to be young sensory cells; those from the central region (right) are believed to be mature sensory cells. The bar (right) represents five microns.

Jeffrey T. Corwin

Dr. Russ E. Davis and Robert A. Weller, graduate student, have developed a new current meter suitable for measurement of near-surface currents that requires a mooring supported by surface flotation. The need for sensing elements other than the conventional rotor/vane elements arises because high-frequency signals, which result from surface waves and wave-induced mooring motion, lead to rectification when speed and direction sensors are used to infer velocity components. The new meter is based on a pair of propeller sensors that separately sense the components of velocity along two orthogonal and horizontal axes.

Extensive laboratory tests have demonstrated the capabilities and limitations of the sensors and the meter as an entire system. The propeller responds linearly to the velocity component parallel to its axis to within 1 percent; the threshold is about 1 cm/sec. In the presence of vigorous oscillatory motion, the time-average response deviates from the linear, steady, flow calibration. If the oscillatory flow velocity and period are v and τ, respectively, the sensor underresponds to the mean flow velocities when $v/\tau > 25$ cm/sec. Thus some deterioration of response would occur when measuring mean surface currents in the presence of 3-m high, 7-second waves. This underresponse in vigorous oscillatory flows appears to be the only nonideality of the sensor.

Work has been completed on a vector-averaging circuit to allow long-term measurement. The meters have been used successfully to profile the Pacific Equatorial Undercurrent during August 1976, to gather extensive profiles of currents in the upper 100 m off San Diego, and to monitor very nearshore currents off the San Onofre Nuclear Generating Station, southern California.

Dr. Jean H. Filloux and his group have completed the fabrication of a fleet of seven pairs of sea-floor, electric-field recorders and magnetic variographs. The electric-field recorders are second generation instruments following those developed for the Mid-Ocean Dynamics Experiment (MODE) in the Atlantic during 1974; however, the magnetic variographs are new.

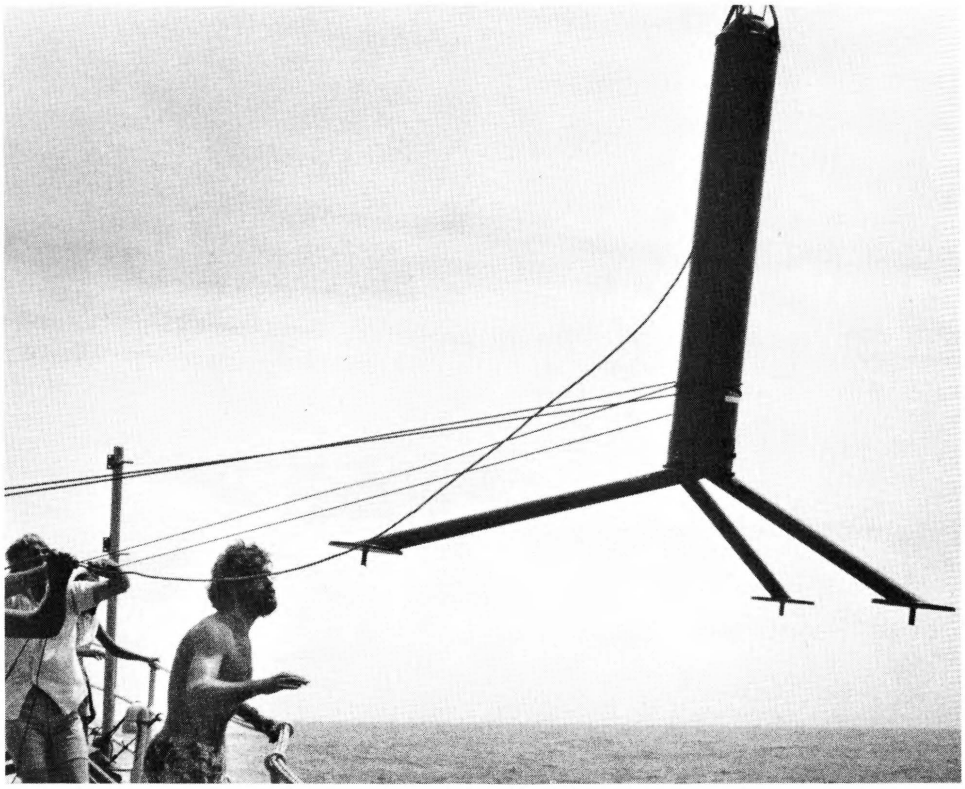
Knowledge of the horizontal electric field on the sea floor permits us to infer important features of the oceanic water motions. If the temporal variations of the magnetic field are also recorded, information on the conductivity distribution in the materials below the sea floor can be derived. The instrument fleet was used in a shakedown cruise in the central North Pacific in August-October 1976.

Dr. Carl H. Gibson's work has been concerned with the development of a towed, ocean-profiling system for use in studies of the mixing and diffusion processes in the upper ocean. High-frequency response temperature, conductivity, and velocity detectors have been developed. Also, a double-hulled, streamlined vehicle was developed that can be decoupled from surface ship motion by a tether-pulley arrangement with a control flap, so it can be flown up and down a support cable under remote control from the ship. Body accelerations are quite low: 10^{-2} to 10^{-1} m/sec^2 compared to much larger values observed on previously towed bodies. Conductivity signals (expressed as temperature) were measured with the 1-mm-resolution, conductivity sensor towed through the San Diego municipal outfall at 40-m depth. A frontal system apparently develops at the outfall, with relatively high-turbulence levels within the frontal zone.

Data taken during the first leg of Indopac Expedition on R/V *Thomas Washington*, by Dr. Kern E. Kenyon, have been processed and some preliminary results are becoming available. This monitoring program consisted of closely spaced (100 km) hydrographic stations along 35°N between San Diego and Yokohama, Japan.

Two parameters in particular were measured at the 98 stations: sea-surface temperature and thickness of the surface layer. The thickness of the surface layer is the depth of the layer of small, vertical, density gradient starting from the surface, and is almost the same as the usual depth of the mixed layer.

Both parameters have different characters in the eastern and western portions of the section as was shown by the larger (>1,000 km) horizontal scale in the east and smaller (500 km peak to peak) scale in the west. The two parameters are approximately directly related, independent of scale, across the entire section; for example, where the surface temperature is relatively large, the surface-layer thickness is relatively large also, and vice versa. Other parameters measured simultaneously in the upper layers show the same east-west contrast in character, including salinity, oxygen, chlorophyll, and nutrients. The smaller-scale variability in the west may be related to meso-scale eddies, rings, or meanders associated with the Kuroshio Current and its extension. The large-scale variability in the east (the "warm pool") is the subject of a continuing investigation, the long-range goal being to discover the interaction between the warm pool and the weather. Further measurements of the warm pool will be obtained in the summer season on the last leg of Indopac Expedition.



A newly developed magnetic variograph used on the ocean floor in measuring the magnetic variation of the earth's field in three directions is launched in central North Pacific from R/V Alexander Agassiz *as Lloyd A. Green (at rail), a member of Dr. Jean H. Filloux's research group, watches.*

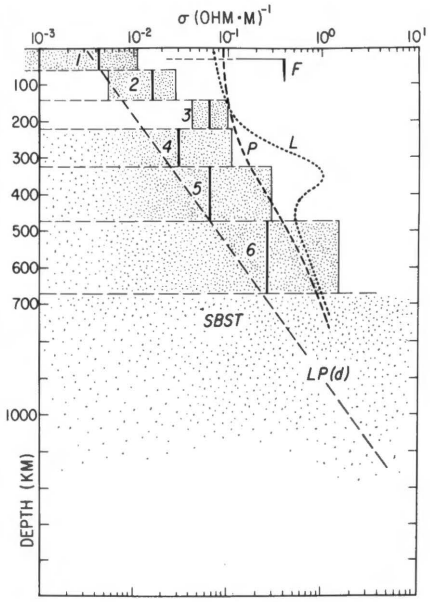
Dr. Jean H. Filloux

Dr. Robert A. Knox has continued efforts to obtain a long series of moored, current-meter measurements from a site in the equatorial Indian Ocean north of the Seychelles. With graduate student Michael J. McPhaden, Dr. Knox has explored certain theoretical aspects of equatorial ocean dynamics. In particular, a very simple model for the interaction between free equatorial waves and a steady mean current is under investigation. Preliminary results show that some observable quantitites are hardly affected by the presence of the mean flow while others, notably the meridional velocity, are markedly changed.

Dr. Theodore D. Foster made some hydrographic stations through the sea ice in McMurdo Sound, Antarctica, along the edge of the Ross Ice Shelf and also through crevasses in the ice shelf about 100 km from the open ocean. The salinities of water samples from one crevasse were found to be nearly identical with those of seawater samples taken in McMurdo Sound, thus indicating direct communication of water under the ice shelf with the open ocean.

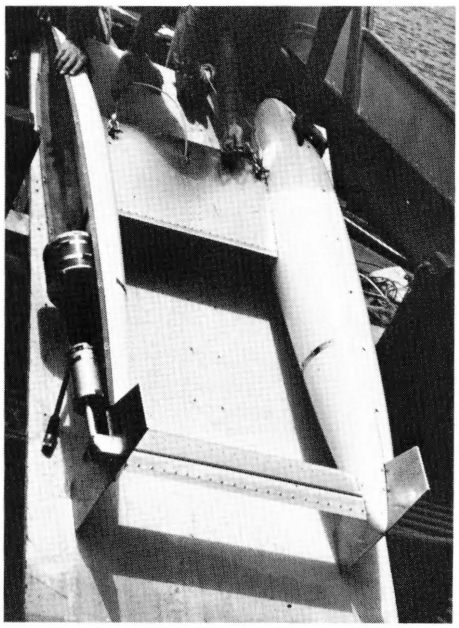
Dr. Jason H. Middleton continued with the analysis of physical oceanographic data taken in collaboration with Dr. Foster during the International Weddell Sea Oceanographic Expedition in 1976. The unique data set obtained from a current meter, which had been moored at the bottom of the Weddell Sea for more than a year, was analyzed and the tidal components were determined. Hydrographic stations repeated in successive years have shown a much greater variability in the water characteristics of the Weddell Sea than had previously been envisaged.

Several projects are under way in Dr. Paul K. Dayton's nearshore ecology group. California kelp associations were the object of intensive study this year. These studies included the construction of life-table parameters and dispersal biology of several kelp species, kelp epiphytes, sea urchin population dynamics, and community ramification's of sea otters in central California. A very productive Antarctic program is under way to study sponge and soft-bottom communities in several McMurdo Sound areas and includes an intensive overwin-



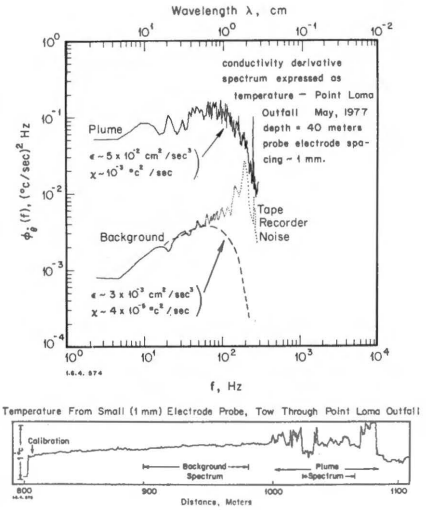
Accompanying diagram prepared by Dr. Jean H. Filloux's research group from results of fleet of instruments used in shakedown cruise aboard R/V Alexander Agassiz *in central North Pacific reflects inferred electrical conductivity distribution in crust and upper mantle at 26°32' N, 151°13' W. Shaded area indicates range of uncertainty. The high conductivity maximum around 180 ±40 km is of great interest, as it may contain the hypothetical, partly molten and more viscous layer or aesthenosphere that allows the rigid oceanic plates to move. Estimated global profiles from other researchers are also shown: LP - Lahiri and Price; P - Parker, and L - Larsen. Results from an earlier sea-floor sounding 600 m off central California coast are indicated by F - Filloux.*

Dr. Jean H. Filloux



Dr. Carl H. Gibson and his colleagues developed a towed, ocean-profiling system to use in studying the mixing and diffusion processes occurring in the upper ocean. The double-hulled, streamlined vehicle is scheduled for an Office of Naval Research-sponsored investigation of the development of the mixed layer in the Gulf of Alaska in September. See Ocean Research Division text for description of vehicle's operation.

Dr. Carl H. Gibson



Utilizing the Gibson-developed, towed, ocean-profiling system (q.v.), ***scientists conducted a pollution survey of the San Diego municipal outfall, in the ocean off Point Loma. Diagram shows conductivity signals (expressed in temperature) measured with the 1-mm-resolution conductivity sensor towed through the outfall at depth of 40 m. Study was sponsored by California State Water Resources Board, and it indicated a frontal system apparently develops at the outfall with relatively high turbulence levels (shown) within the frontal zone.***

Dr. Carl H. Gibson

ter program. The group also investigated the sand-bottom community in the vicinity of Scripps, population biology of cup corals, and the microdistribution and population dynamics of the fauna associated with intertidal algae.

Dr. Mia Tegner has been studying the natural history and population dynamics of red sea urchins, which are the object of a large and growing commercial fishery. One of the goals of this research is to develop management practices that will protect this important member of the kelp-bed community from overexploitation. Studies have shown that fishing removes nursery grounds, as well as reproductive potential. Provisions must be made to leave some sea urchins behind to ensure continued settlement and the regeneration of the population. Dr. Tegner also began work this year on a joint project with the California Department of Fish and Game to develop methods to enhance wild populations of abalones.

Dr. Walter F. Heiligenberg's comparative studies of the electrolocation and jamming avoidance behavior in African and South American electric fish is discussed in detail in the Neurobiology Unit section of this report.

Climate Research Group

The Climate Research Group (CRG) has continued investigating climate variations and the mechanisms causing these variations on both a regional and hemispheric basis. The aim is to predict climate variations one or more seasons in advance. CRG is making progress toward this goal by successfully predicting the severe winter of 1976-77 in the United States with the use of ocean-atmosphere methods. Similar predictions were made independently by four different individuals. A successful temperature forecast for spring over the United States was made by using newly developed concepts of a climate state vector and multiple-field analog prediction techniques.

The pattern that occurred during the winter of 1976-77 was associated with the most energetic mode of climate variability over the Pacific/North American continent. The cause of the unusual winter was the unexpectedly high amplitude of this mode. The amplification and resulting severe winter were apparently caused by the synergistic interaction of several different features in the climatic system. These features, acting together, constituted a positive feedback system that helped to maintain and greatly enhance the mode amplitude.

GEOSECS

The GEOSECS Operations Group, directed by Arnold E. Bainbridge, continued with the production of an eight-volume atlas of Atlantic and Pacific hydrographic and geochemical data. The computerized data base is connected to 4,800-baud graphics terminals at Scripps; Woods Hole Oceanographic Institution, Massachusetts; Lamont-Doherty Geological Observatory, New York, and University of Miami, Florida.

Within the GEOSECS group, the CTD instrumentation and specially developed data-aquisition systems have been used extensively and have been adapted for use aboard Deep Tow and Woods Hole's submersible *Alvin* for the detection of thermal plumes. Traces have been digitized and malfunctions tabulated for more than 10,000 XBT droppings.

A general purpose FORTRAN compiler has been written for the META-4 (1800) computer. Assemblers for microprocessor codes have been written for the META-4 that allow program

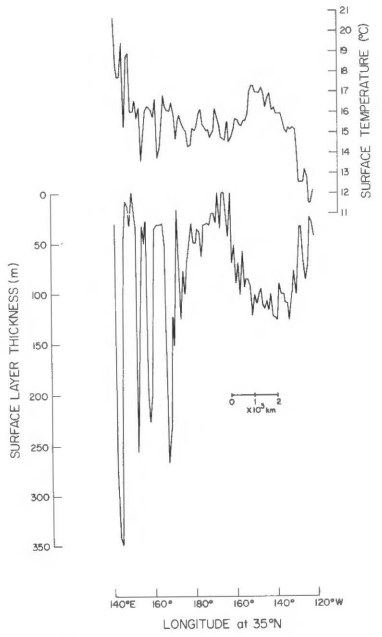


Diagram indicates sea-surface temperature and thickness of surface layer as two parameters measured at 98 hydrographic stations along 35°N, starting near San Diego and ending near Yokohama, Japan. Work was accomplished during R/V Thomas Washington***'s Leg 1 of Indopac Expedition. See explanation of research in Ocean Research Division text.***

Dr. Kern E. Kenyon

changes to be made during instrument development.

Other GEOSECS activities include management of the Bureau of Land Management's Southern California Bight Project data base. The group participated in and aided in the data reduction of various cruises carried out by several universities and the Office of Naval Research. The GEOSECS group is preparing for its third major expedition in late 1977, a four-months cruise to the Indian Ocean aboard R/V *Melville.*

NORPAX

NORPAX 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 their 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.

Scripps is one of the major institutions participating in the program and also serves as the center for administration of the NORPAX project, which includes 34 scientists from 14 universities. Three major activities are being pursued at Scripps: 1) statistical/analytical studies of the ocean and the atmosphere and their interaction; 2) field studies on the variability in heat content and surface currents in the upper waters of the mid-latitude North Pacific, and 3) a field study designed to test the feasibility of making long-term measurements of the thermal structure in the equatorial Pacific.

Substantial progress has been made in the utilization of large-scale air/sea interaction concepts in short-period climatic forecsting. A striking example is Dr. Jerome Namias's prediction of the severe 1976-77 winter weather over the eastern United States (see ORD-Climate Research Group). These forecasts are based partly upon a balance, or imbalance, between air circulation and sea-surface temperature and on feedback relationships between ocean and atmosphere in the North Pacific. Studies are under way to analyze the causal mechanisms for cases of imbalance and the ways in which the balance is eventually restored.

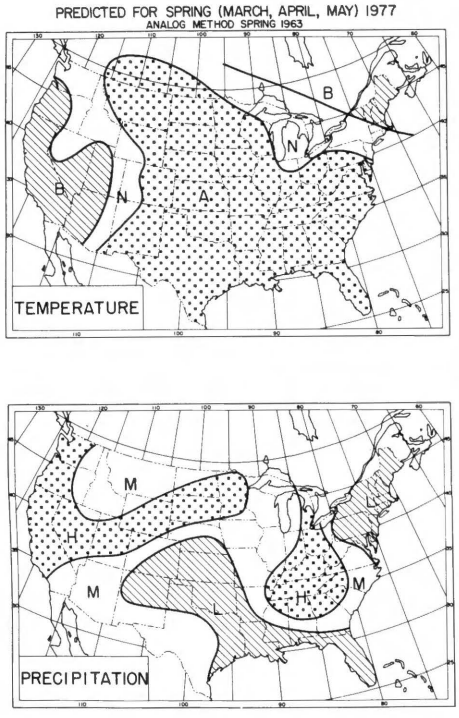
Preliminary results of studies relating the 1976 far-western United States drought and European drought to surface water temperatures indicate the role of atmospheric subsidence and the influence of the extremely strong westerlies north of 50°N with concomitant strong and laterally extensive subtropical anticyclones. This drought appears to be the culmination of a long-period trend begun early in the 1970s.

Empirical orthogonal functions have been generated for North Pacific and North Atlantic sea-surface temperature fields, hemispheric sea-level pressure and 700 mb height, and for North American temperature and precipitation. The functions are being used to study large-scale linkages between ocean and atmosphere, to compare scales and processes, and to examine atmospheric linkages between the two oceans and between oceans and the continent.

Associated statistical/analytical studies by Dr. Davis have continued to probe the kinds of sea-level pressure predictability possible from mid-latitude sea-surface temperature. Using seasonally stratified statistics derived from the thirty-year period, 1947-1976, Dr. Davis finds intrinsic predictability of autumn and winter sea-level pressure; yet none for spring and summer. How-

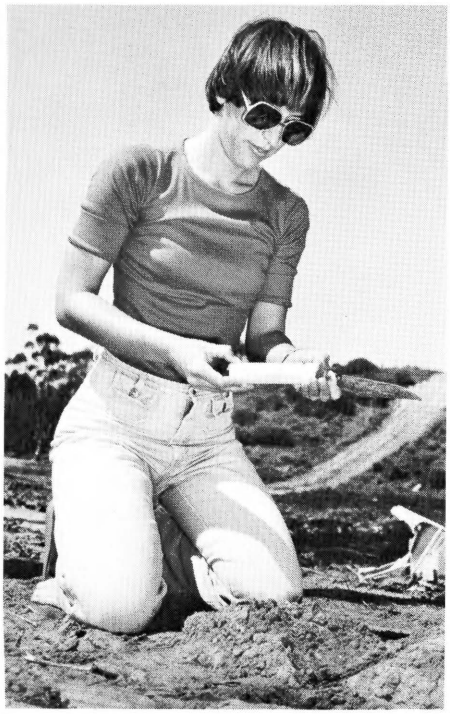
Dr. Bernhard Lettau, National Science Foundation's (NSF) Division of Polar Programs, lowers water-sampling bottle with protective cage through hole in the sea ice near McMurdo Station, the principal United States scientific research base in Antarctica, in December 1976, during NSF's Ross Ice Shelf Project. Bottle was specially designed for hydrographic casts through the ice and is deployed with a portable winch and a pulley on an A-frame (at right). Dr. Theodore D. Foster and researchers from many U.S. institutions participated in the project.

Dr. Theodore D. Foster

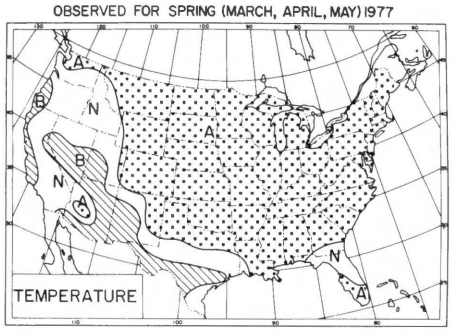


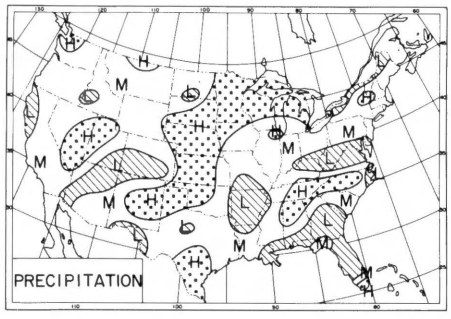
Successful experimental forecast by Climate Research Group for spring of 1977 is indicated in side-by-side temperature and precipitation patterns predicted and observed. See explanation in Ocean Research Division text.

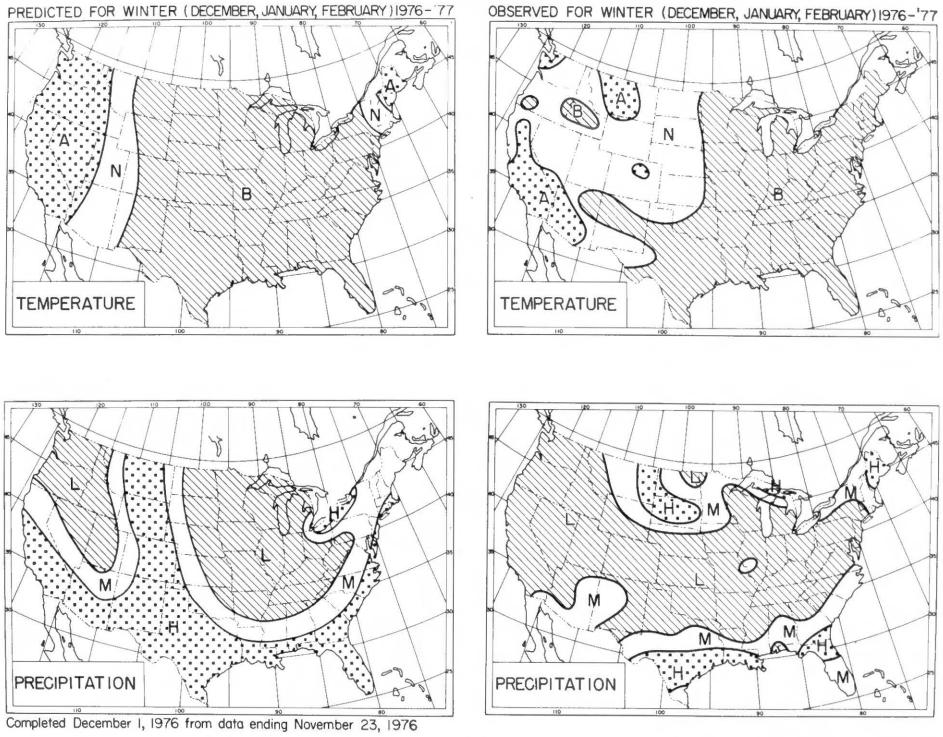
Dr. Tim P. Barnett



Dr. Patricia Masters examines vial of sucrose she extracted from soil in North San Diego County. Ten vials were implanted in area a year ago to monitor soil temperatures. Analyses of contents of vials provides temperature cross-check for the amino-acid racemization dating of fossils from the area by Dr. Masters and other members of Dr. Jeffrey L. Bada's research team. Team members have also implanted vials in France, Greece, Israel, and Spain for studies in those countries.







Successful experimental prediction by Climate Research Group of temperature and precipitation for the severe winter of 1976-77 is shown side-by-side with same patterns observed during the season. See Ocean Research Division text for explanation.

Dr. Jerome Namias

ever, the notion that the evidenced predictability results primarily from oceanic thermal influences (indicated by sea-surface temperature) on the atmosphere (sea-level pressure) is still in question, since prior sea-level pressure is nearly as useful in making predictions as is sea-surface temperature. Work is now under way to determine whether seasonal, oceanic, sea-surface temperature and sea-level pressure indicators can be of consistent use in predicting seasonal anomalies over the North American continent.

Two years ago, a group within NORPAX began the Anomaly Dynamics Study to investigate how the variability in the fluxes of heat and momentum between ocean and atmosphere alter the thermal structure in the mid-latitude North Pacific. Two field programs at Scripps are at the core of this endeavor. The first is TRANSPAC, an expendable bathythermograph (XBT) field program headed by Drs. Warren B. White and Robert L. Bernstein. This program uses XBT data taken randomly by 25-30 ships-of-opportunity (commercial ships outfitted with XBT systems) that ply the trade routes through the area. These data allow scientists to construct monthly maps of the thermal structure in the upper 500 m of ocean on a 2°-latitude-by-5°-longitude grid from one side of the ocean to the other from 30-50°N. The second field program, headed by Gerard J. McNally, uses groups of 20-40 satellite-tracked, freely drifting and drogued buoys to measure the surface currents for as long as one year over the eastern mid-latitude North Pacific.

From the TRANSPAC XBT field program, Drs. White and Bernstein have detected large-scale (~2,000 km) internal waves traveling westward along the main thermocline in the eastern and central North Pacific at 15-20 cm/sec. These waves appear to be generated by wind forcing at the sea surface, although further observations will be needed to confirm this. In the western North Pacific, meso-scale (~200 km) internal waves traveling westward at approximately 5-10 cm/sec have been found to dominate the variability in the main thermocline. These meso-scale waves are associated with a significant eddy flux of heat poleward across the North Pacific Current from a subtropical gyre to the subarctic gyre, not unlike the eddy flux of heat in the atmosphere from the equator to the pole across the westerly wind system.

From the satellite-tracked, freely drifting buoys, McNally has found evidence that the large-scale surface currents travel 30-40° to the right of

Dr. Robert E. Stevenson (left), of the Office of Naval Research (ONR) liaison office at Scripps, presents a letter of appreciation from Rear Adm. Robert K. Geiger, USN, Chief of Naval Research, Washington, to Dr. Richard T. Wert at the time of Dr. Wert's retirement from Scripps. Prior to assuming the program managership of NORPAX, Dr. Wert had served as a physical oceanographer in ONR's Ocean Sciences and Technology Division.

Robert P. Huffer (second from right) presents certificates of appreciation on behalf of Scripps to group of Japanese shipping representatives in Tokyo. Their companies participated in NORPAX's TRANSPAC (trans-pacific) Ship-of-Opportunity XBT field program.

NORPAX

the ambient wind, nearly in agreement with a theory proposed by V. W. Ekman nearly 75 years ago. These wind-driven currents are found to play an important role in the seasonal variations of sea-surface temperature by advecting warm water north and cold water south, especially in winter when these currents are ~20cm/sec, nearly an order of magnitude larger than in summer.

This autumn, a three-month field study is being conducted in the central equatorial Pacific for the purpose of measuring the scales of variability in the major zonal equatorial currents from 15°S to 20°N. This program will test the feasibility of measuring for periods of years both the large-scale structure of the upper ocean from ships-of-opportunity and surface currents from drifting buoys, moored current meters, and sea-level stations on islands. Drs. William C. Patzert and Tim P. Barnett will use a Navy P-3 aircraft to make weekly, meridional, airborne-expendable-bathythermograph sections between Hawaii and Tahiti. Drs. Davis and Knox will use specially designed, moored, current meters, that allow for direct current measurements in the near-surface wind wave zone, to investigate the space and time scales in the surface current field. McNally will deploy satellite-tracked, freely drifting buoys that will follow the zonal flow of the North Equatorial Current and Equatorial Countercurrent, portraying the meanders and eddies that exist in these major current systems. Dr. Knox will make hydrographic surveys between Hawaii and Tahiti, producing meridional sections of density that will support the temperature sections from the aircraft. It is expected that these studies will lead to a more ambitious measurement program that will coordinate with the First GARP Global Experiment in an intensified, atmospheric, ocean, global measurement program.

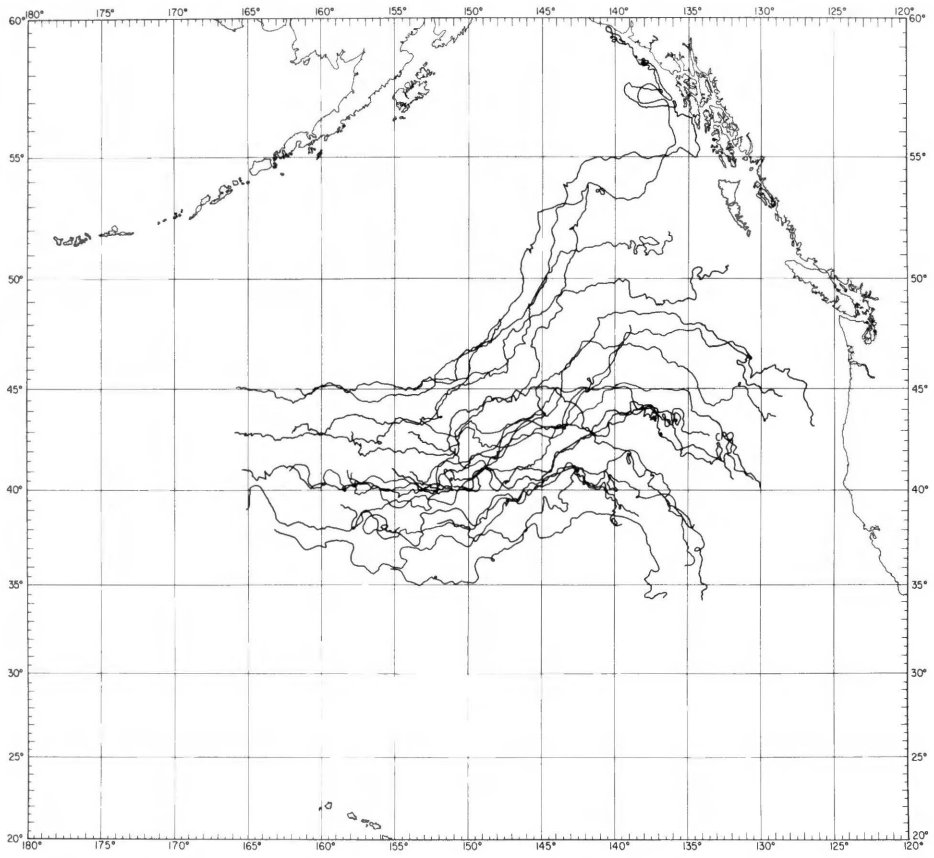
Shore Processes Study Group

The Shore Processes Study Group (SPSG), under Drs. Douglas L. Inman, Clinton D. Winant, and Robert T. Guza, is investigating physical processes of the nearshore environment. Research objectives of the group include 1) field and laboratory measurements of wind, waves, currents, and sediment transport in the coastal zone; 2) use of these basic data to identify and study the important physical processes operative in the nearshore environment, and 3) application of the understanding of these processes to the solution of environmental problems.

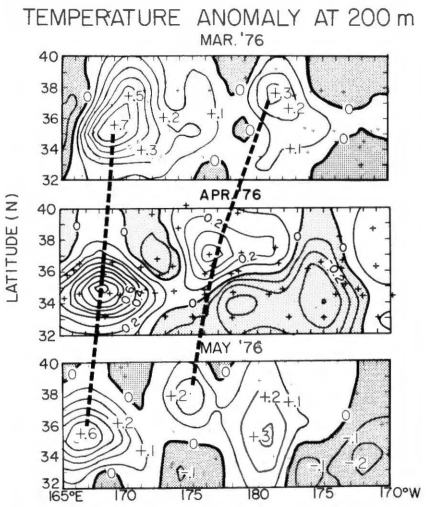
The basic research tool of the SPSG is the Shelf and Shore (SAS) simultaneous data-aquisition system that was developed specifically for use in the nearshore environment. This system consists of several shelf stations, which are deployed offshore as sensor platforms, and a shore station for receiving and recording data. The shelf station is a buoyant spar that is anchored to the bottom and contains a transmitter at the top for telemetering data to shore. Various sensors can be mounted on or near the station for measuring environmental parameters. The shore station receives data from several shelf stations simultaneously for synoptic observations. Real-time data processing is accomplished by a minicomputer that has a direct communication link with the shore station.

One of the most significant activities during the past year was a sustained field study at Torrey Pines Beach, San Diego, during March 1977, as part of the National Aeronautics and Space Administration's (NASA) SEASAT West Coast Experiment. This field study provided a fully instrumented site as a "ground truth" point for the NASA experiment that involved the testing of remote sensors carried in high-flying aircraft. The overall objective of the experiment was to document changes in waves during their passage from the open ocean past the offshore islands to the mainland shore. The field study at Torrey Pines Beach involved the installation of several shelf stations with pressure sensors to make up a linear array for the measurement of directional wave spectra. Also, current meters, run-up meters, and other sensors were installed on the beach for the measurement of various environmental parameters. Measurements were then made on a regular basis with this sensor system during the overflights that provided the data necessary to verify the remote imagery, which showed the passage of waves into the coastal zone. Graduate student Steven S. Pawka is analyzing the results of this experiment to determine the effect of the offshore islands on the mainland wave climate.

The study at Torrey Pines Beach in March also provided an opportunity to collect data concerning wave-wave interactions and sand transport by waves on beaches. Dr. Guza and others used sensors to make measurements of currents in the surf zone and wave run-up at Torrey Pines Beach. These measurements are being analyzed to determine the presence of long-wave modes in the surf zone and their effect on currents. Dr. Inman, graduate student James A. Zampol, and Earl A. Murray made measurements of suspended and bed-load transport of sediment in the surf zone during the field study to clarify the relationship between suspended and bed-load sand transport by waves in the surf zone. These measurements were also intended to provide information on



Trajectories of individual buoy locations for September 1976 through June 1977, from 25 satellite-tracked, freely drifting buoys moving east from their initial deployment at 155-165°W, 37-45°N, in September 1976.
NORPAX



Sequence of three, temperature anomaly maps for western mid-latitude, North Pacific, from March 1976 to May 1976 shows westward propagation of meso-scale waves in main thermocline constructed from temperature data collected by NORPAX's TRANSPAC (transpacific) XBT field program.
NORPAX

how to improve the sediment-sampling procedure in future field experiments.

Drs. Winant, Davis, and Robert W. Severance, Jr., and graduate student Alan W. Bratkovich have been carrying out an intensive field study of coastal currents and temperature measurements at Del Mar and San Onofre, California. These studies are intended to provide background information concerning the current and thermal regime in shallow coastal waters.

Dr. Inman, Charles E. Nordstrom, and graduate student James A. Bailard carried out a research project using the principle of duct-flow fluidization to open an inlet channel at Los Peñasquitos Lagoon, near Del Mar, California. This research project was undertaken to apply the previously developed fluidization technique to the problem of maintaining an inlet to a coastal lagoon of limited tidal prism. Los Peñasquitos Lagoon was chosen as the study site be-

Utilizing fluorescent tracer, members of Shore Processes Study Group collect sand samples from surf zone at Torrey Pines Beach, San Diego, during longshore transport study. From left: Dr. Christopher von der Borch, Flinders University, Bedford Park, South Australia, and graduate students James A. Bailard and Scott A. Jenkins.
Shore Processes Study Group

cause of the intermittent nature of its inlet. When the lagoon inlet closed in February 1977, a fluidization pipe was installed to create a new inlet channel. With the use of a 45-m long, 10-cm diameter fluidization pipe and two portable water pumps, a new inlet channel was cut across the sand plug. This test of the procedure proved that it could be used in this application.

Continuing a three-year sediment management research program for the Naval Facilities Engineering Command, Drs. William G. Van Dorn and Scott S. McElmury supervised the design and installation of a 10,000-m^2, prototype, hydraulic-jet, sediment-sweeping array on the mud floor of a pier basin at the Mare Island Naval Station, Vallejo, California. The system utilizes a 150-hp electric pump to discharge seawater at high velocity through five consecutive branches of 14 2-cm diameter jets, with the object of resuspending and effluxing to the tide stream the daily accumulation of the fine sediment brought into the basin by normal siltation processes. The discharge lasts for 35 minutes and is actuated by tidal elevation so as to synchronize with ebb flow at the bottom, which carries the effluxed sediment away.

Despite an abnormally dry year, during which the total sediment burden in the San Joaquin and Sacramento river system was only about 20 percent of normal, the array has functioned as intended for six months, and has demonstrated its capability to prevent about two-thirds of the deposition observed at an adjacent control site.

Mt. Soledad Radioisotope Laboratory

Dr. Robert C. Finkel, at the Mt. Soledad Radioisotope Laboratory, has been preparing equipment for studies of the Pb-210 and Po-210 distribution in the Indian Ocean. Water samples will be collected during the GEOSECS Indian Ocean Expedition. The results of this work will be applied to understanding both the hydrography of the Indian Ocean and the pathways followed by trace metals in the oceans.

In another study, preliminary work has been completed on a program to measure the U-234/U-238 isotope ratio in springs as a possible earthquake precursor. Samples for this study will be collected in California from the Elsinore, San Jacinto, and San Andreas fault systems.

Also at the Mt. Soledad Radioisotope Laboratory, Dr. Theodore R. Folsom continues his review of radioactive traces concentrated in Pacific albacore tissues. He is gaining a better understanding of mechanisms controlling the fate of six different elements that had entered the ocean as fallout. A mathematical model, which uses trends reported for global fallout, appears to predict satisfactorily the residence times in surface waters of several unlike elements, such as cesium, zinc and silver, and plutonium. Half-time residence appears to vary from 0.7 year for fallout iron to about six years for cesium.

Physiological Research Laboratory

The Physiological Research Laboratory (PRL) is one of the principal links between UC San Diego School of Medicine and Scripps Institution of Oceanography. Research activities are currently oriented toward the physical behavior of gases under high pressure, physiology and biochemistry of deep-sea organisms, respiratory physiology and energetics of marine mammals, lower vertebrates and invertebrates, comparative aspects of acid-base regulation, biophysics of solutes in thermal gradients and transduction of neural information. The newly formed Marine Biomedical Council, chaired by Dr. Fred N. White, director of PRL, is currently engaged in developing joint Scripps/UC San Diego School of Medicine interdisciplinary programs.

Dr. White joined PRL as its new director in January 1977. Dr. White's research activities are concerned with the comparative physiology of the cardiorespiratory system of lower vertebrates and invertebrates. He has recently demonstrated, with a surgical team at UC Los Angeles, that regulating the acidity of the body fluids, in a manner similar to that observed in cold blooded animals, such as fishes, produced marked improvement in the function of the canine heart at low temperature. Possible application of these results to human surgery at low temperature is under assessment at the UC Los Angeles Center for the Health Sciences.

Dr. A. Aristides Yayanos continues his research on the biology of marine organisms, which are under conditions of high pressure. Amphipods inhabit a large portion of the deep ocean and successful retrieval under conditions that characterize their natural habitat has been a major obstacle to their study. Two pressure-retaining amphipod traps, designed by Dr. Yayanos, have been successfully recovered from the central North Pacific with living amphipods from a depth of 5,700 m. On board R/V *Thomas Washington*, the animals were maintained at 565 atm. pressure and the chambers circulated with fresh seawater and nutrients at this pressure. Samples of fluid were obtained for biochemical studies and observations were made on activity rates and responses to light. Living amphipods, under pressure, were successfully transported by air to Scripps, where, for the first time, more

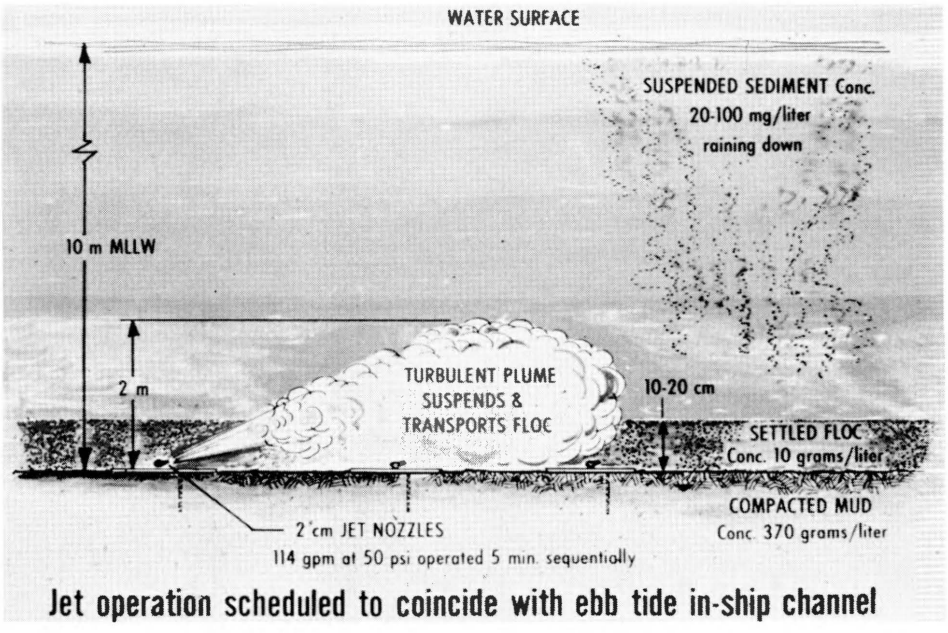
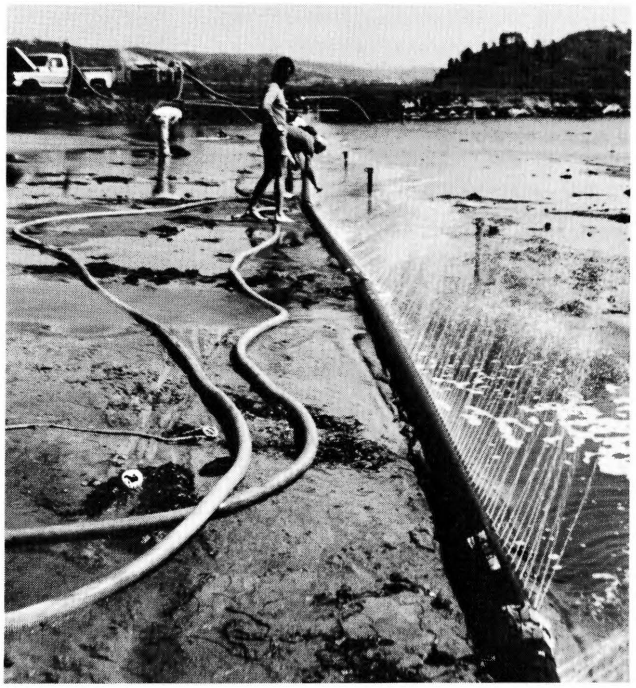


Diagram shows operation of hydraulic jet sweeping array installed by Shore Processes Study Group at Mare Island Naval Station, California.

Shore Processes Study Group

Duct-flow fluidization cuts inlet channel across beach as part of Sea Grant research project carried out by members of Shore Processes Study Group at Los Peñasquitos Lagoon, San Diego.

Shore Processes Study Group



Water jets are tested before fluidizing pipe is rotated to open Los Peñasquitos Lagoon, San Diego, by sand fluidization. Work was part of Sea Grant research project carried out by Shore Processes Study Group.

Shore Processes Study Group

detailed studies of their biochemistry, energetics, and behavior will be possible.

Dr. Edvard A. Hemmingsen and graduate student, Wayne A. Gerth, are studying bubble nucleation in gas-supersaturated liquids. These studies are directed at gaining further insight into the nucleation phenomenon and the factors that affect it. Emphasis has been placed on liquid and liquid-solid interface systems, which have direct implications on the formation of bubbles in organisms, such as occur during certain conditions of decompression. In the problem of bends; for example, fundamental information as to where and how the bubbles form, and the conditions that promote their formation, are largely lacking. The ongoing studies may provide useful tools and concepts for solving some of these problems. Related to these investigations, measurements of the solubilities of gases at high pressures in water, aqueous solutions, and other liquids are being made.

Investigations of respiratory adaptations in aquatic vertebrates continue to be the major thrust of Dr. Gerald L. Kooyman's research. Funding for this work comes from a National Institutes of Health project on lung structure and function, which is headed by Dr. John B. West, UC San Diego School of Medicine. These studies deal with the structural nature of the lung and how it relates to gas exchange and ventilation. The Scripps portion of this research concerns the behavior, physiology, and anatomy of those aquatic vertebrates that swim at high speeds and those that dive to great depths. These groups are being compared to less vigorous aquatic forms and terrestrial animals.

Mechanical properties of marine mammal lungs are being studied as well as the geometry of the lung's airway systems. The microanatomy of the smallest airways are also being examined by light microscopy. Concurrent with these studies are the investigations of the degree of lung compression when seals and sea lions dive to great depths. The effects of compression are quantified by measuring the amount of pulmonary shunt that occurs as a result of the compression.

Related to these studies were the topics of one doctoral dissertation and one master's thesis. The dissertation completed by Everett E. Sinnett addressed the problem of pulmonary circulation in the harbor seal including a comparison of its responsiveness to hypoxia with that of the dog. The work was supported jointly by and utilized the UC San Diego School of Medicine's laboratories of Drs. Eric A. Wahrenbrock, West, and James W. Covell, as well as those of PRL. Sinnett found that during prolonged dives mean pulmonary arterial pressure fell to very low values and that during extended diastoles blood flow through the pulmonary vascular bed ceases. There also seems to be an age-related response to alveolar/hypoxia in which this response is lost in the older animals.

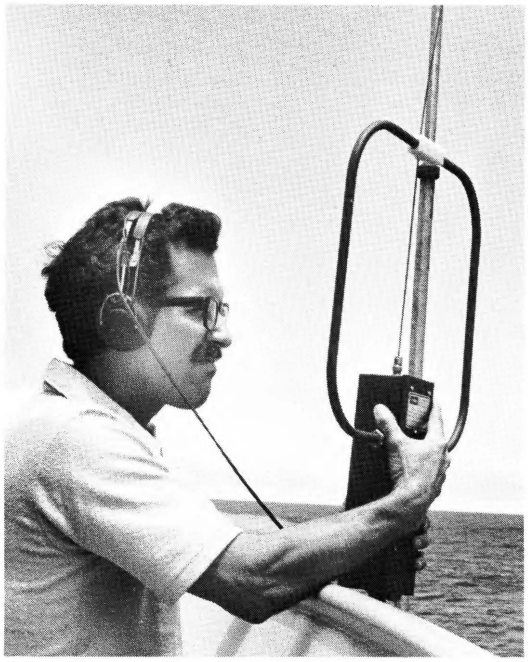
Richard C. Matthews, San Diego State University graduate student, completed his Master of Science thesis on a study of the mechanical properties of the lung of trained sea lions. Drs. Roger Carpenter, San Diego State University; West, as well as PRL assisted with this research. Matthews found that sea lions can attain exceptional peak expiratory flow rates and maintain these flows at low lung volumes.

Complementary to these investigations are studies of the diving behavior of marine mammals. The behavior is determined remotely by releasing animals with recording instrumentation that will continuously record every dive for a period of 2½ weeks. The diving studies so far have included three species of fur seal. Emperor penguins and Weddell seals will be included in the near future.

Another project under investigation is the understanding of the energy production of sea otters and the effects oil contamination of the fur, such as might occur during an oil spill, will have on this production. In the course of this work, an analysis of oil-decontaminating materials and the procedures of their utilization will be assessed.

Dr. Harold T. Hammel and James E. Maggert have been investigating the Soret effect in aqueous solutions of the

On board R/V Thomas Washington, *Dr. A. Aristides Yayanos listens to a radio receiver for transmissions from a recovery buoy attached to his free-vehicle high-pressure aquarium that was sent into the deep sea. Later, he removes the bait basket and protective metal box from the 23 x 23 x 8-cm aquarium, which contains live amphipods, the first time animals had survived ascent from the deep sea. They were captured at a depth of 5,700 m in the central North Pacific Ocean during Indopac Expedition.*
Dr. Elizabeth L. Venrick



electrolytes and nonelectrolytes in extracellular and intracellular fluids. When a temperature difference is maintained across a solution, Soret found that solute partially separates from solvent such that the concentration of solute near the heated surface is less than the concentration near the cooled surface. The ratio of electrolyte in concentration difference across the thermal gradient existing between 273°K and 323°K is approximately 0.85. A matrix was introduced into the Soret cell along with the solution to minimize convection in a 1 osmolal NaCl solution. For this purpose glass beads, one percent gelatin, polyurethane foam, etc., were tried with some reduction of the concentration ratio from 0.95 to 0.9. When the Soret cell was filled with Whatman #40 filter paper along with 1.0 osmolal aqueous solution of NaCl, C_{323}/C_{273} became very large (> 100) as potable water (< .03 osmolal) accumulated at the cooled surface and > 4 osmolal solution accumulated at the heated surface. Similar effects were produced in 1.0 osmolal aqueous solutions of glycerol, sucrose, and seawater. It would appear that water vapor diffuses from a higher vapor pressure near the hotter surface to a lower vapor pressure near the colder surface by diffusion through entrapped air within the filter paper. The diffusion coefficient for water vapor through air is approximately 10^4 times the diffusion coefficient for a solute through liquid water. Thus, water that evaporates and concentrates the solute near the hot surface diffuses readily to condense and dilute the solute near the cold surface. The diffusion of water vapor may be a few orders of magnitude more rapid than the diffusion of solute and accounts for the super separation of solute from solvent. An application for a patent for this process has been filed on behalf of The Regents of the University of California.

Dr. Eckhart Simon at the Max-Planck-Institut für Physiologische und Klinische Forschung, Bad Nauheim, West Germany, and Dr. Hammel have collaborated on an investigation of neurons in the hypothalamus of the conscious Peking duck and have recorded many neurons that increase firing rate with increasing temperature, several that are temperature insensitive, and a few that increase firing rate with decreasing temperature. These are the first recordings of this kind in the bird and the results are almost identical with comparable results from mammals. This is surprising since Drs. Simon and Hammel, and other coauthors, have already reported that cooling the hypothalamus of ducks and the Adélie penguin inhibits shivering and vasoconstriction, whereas hypothalamic cooling induces or increases shivering and vasoconstriction of cutaneous blood vessels in mammals. UC San Diego School of Medicine graduate student Randall E. Kaul, has demonstrated that a part of the increase in salt secretion from the nasal salt gland of the Peking duck during an intravenous infusion of a NaCl solution must be attributed to volume receptors, in addition to the osmoreceptors. Dr. Mark L. Laudenslager has completed an investigation of the oxygen consumption and evaporative water loss from the chukar partridge exposed to dry air temperatures from -3° to 30° C. He has also shown that the preferred thermal environment of this bird is identical with its thermal neutral zone.

Drs. James A. Raymond, Alaska King Salmon Program, Fairbanks, Alaska, and Arthur L. DeVries, University of Illinois, Urbana, conducted studies on serum proteins and glycoproteins that protect polar fishes from freezing. Measures of antifreeze concentrations in ice and scanning electronmicrographs of freeze-dried antifreeze solutions indicated that the antifreezes are incorporated in ice during freezing. The antifreezes also have a pronounced effect on the crystal habit of ice grown in their presence and the antifreezes absorb to ice surfaces inhibiting crystal growth. These studies aid in removing the mystery, which surrounded the capacity of polar fishes to withstand freezing temperatures and avoid cell death caused by ice crystal damage. Results of this work were published in the proceedings of the National Academy of Sciences.

The "wick technique," a device developed for measuring tissue pressure, has found a clinical application. First developed for animal studies by Dr. Per F. Scholander and Dr. Alan R. Hargens, UC San Diego School of Medicine, the device is now being used to assess the

state of tissues and the level of circulatory impairment following injury. Accurate assessment of the tissue pressure provides more precise information on which fluid replacement programs can be designed in specific conditions including shock. Drs. Wayne H. Akeson and Hargens, UC San Diego School of Medicine, have adapted the technique to the clinical setting.

The long standing collaboration of Drs. Scholander and Hammel was formalized in their monograph, *Osmosis and Tensile Solvent* (Springer-Verlag).

Visibility Laboratory

In the ocean environment light constitutes a vital input to the food-chain process. In both the atmosphere and the ocean, visible light is the basis for the observation associated with scientific investigations. These 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. Laboratory scientists also study the fundamentals of extraction and interpretation of the received image information.

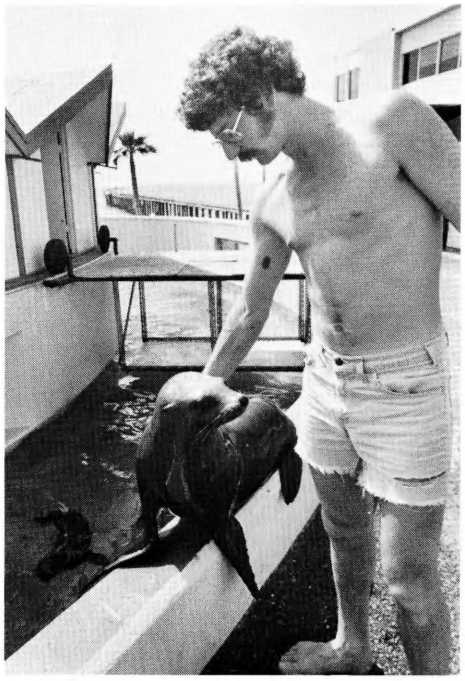
Optical Oceanography

The remote sensing of ocean properties by means of visible light continued as a major laboratory involvement. Examples of information of interest include the synoptic assessment of the productivity of the world's oceans, charting the movement of certain water masses, and the study of other oceanographic processes that cause a characteristic change in the optical signal returned from the ocean floor, the water, or the water surface. Roswell W. Austin, with assistance from Drs. Raymond C. Smith and Wayne H. Wilson, studied the oceanic and atmospheric factors affecting the signal available to a remote ocean color sensor. Computer techniques are being developed for the analysis of remote scanning spectroradiometer data to remove the veiling radiance of the atmosphere and enhance its sensitivity to ocean features. Austin has served on the National Aeronautics and Space Administration (NASA) Nimbus Experiment Team for the Coastal Zone Color Scanner to be launched in 1978. Laboratory staff has been active in the planning of a cruise for the development of uniform surface truth acquisition procedures.

Studies of the propagation of light in seawater have been continued by Drs. Smith and Wilson with assistance from Theodore J. Petzold. Experiments have been conducted to determine the characteristics of images recorded in highly scattering waters. Computer simulation of these imaging characteristics are being explored by James L. Harris, Sr., and Benjamin L. McGlamery.

Dr. Smith has started a program of measuring the penetration of ultraviolet radiation into a natural water. An increase in the incidence of solar ultraviolet radiation upon oceans and lakes, as a consequence of anthropogenic diminishing of the ozone layer in the stratosphere, might well have a significant effect upon primary producers and other organisms in these natural waters. Reliable estimates of the potential effects of increased radiation upon the aquatic environments require accurate measurements of the penetration levels. Appropriate instrumentation is being developed and complementary measurement of important ancillary physical and biological data including Dissolved Organic Material (DOM) and pigment concentration are being planned.

John E. Tyler continued his exploration of the quantum efficiency of photosynthesis. After analyzing the existing data and outlining its deficiencies, he has outlined the requirements for appropriate instrumentation.



James G. Herpolsheimer, animal caretaker with Physiological Research Laboratory (PRL), gives pat on the back to Trisha, a California sea lion that playfully jumped on wall enclosing PRL testing pool.
Photo by Don Bartletti, courtesy of *Oceanside Blade-Tribune*

Gerald D. Edwards supported a measurement program of the Naval Oceanographic Office, conducted off the coast of Spain. He produced depth profiles of scattering and absorption using Visibility Laboratory instruments.

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-

Margaret, a sea otter, floats on her back in Physiological Research Laboratory testing pool. She and another otter, not shown, helped scientists check effects of oil on the otters' fur in the U.S. Bureau of Land Management Study.

130 aircraft assigned to the laboratory for this purpose.

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 gather detailed data of the vertical profile of atmospheric properties. The aircraft is usually operated in conjuction with a similarly instrumented ground station, so that corresponding zero-altitude data can be added to the vertical profile.

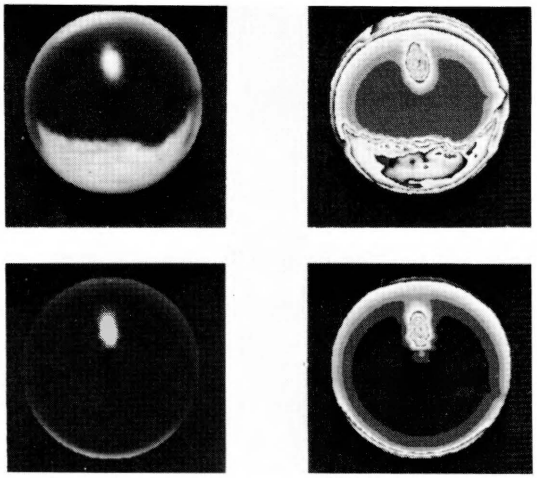
The principal activity for the year was the reduction of data collected during a 62-day European field trip in which the C-130 and a four-man technical team collected atmospheric data in West Germany, England, Netherlands, and Denmark. Preparations were also made for another European field trip planned to sample a different seasonal condition.

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. These facilities serve several different research activities.

McGlamery has continued his computer simulations of techniques for achieving improved resolution for telescope viewing. Earth-based telescopes are presently limited by the nonhomogeneous optical properties of the atmosphere. Within the last several years new techniques for improving telescope resolution have evolved and attracted national interest. The techniques used the physical deformation of a secondary mirror in real time to compensate for the atmospheric turbulence. The procedures involved are quite complex and difficult to analyze, but the computer simulation is able to provide a means of evaluating the potential performance of postulated methods.

The Visibility Laboratory image-processing research facility is located off-campus in Point Loma. During the year, a remote terminal has been designed and constructed, and will be installed in the NORPAX building on Scripps campus. This equipment will permit an investigator located at the typewriter-like terminal on the Scripps campus to command the operation of the Point Loma computer, receive numerical data, and see the pictorial material being processed on a television screen. The two facilities will be linked by telephone lines. The purpose of the remote terminal is to allow exploration by Scripps researchers of the application of these digital capabilities to a wide range of oceanographic activities including enhancement and information extraction from satellite imagery.



Sun glitter patterns recorded by lower hemisphere scanner of C-130 aircraft during Visibility Laboratory investigations. Left-hand pictures are for 3-km altitude (top), and .03-km altitude (bottom), corresponding to sun zenith angles of 39.3° and 36°. Right-hand pictures are a form of computer enhancement designed to show subtle detail.
Visibility Laboratory

Institute of Geophysics and Planetary Physics

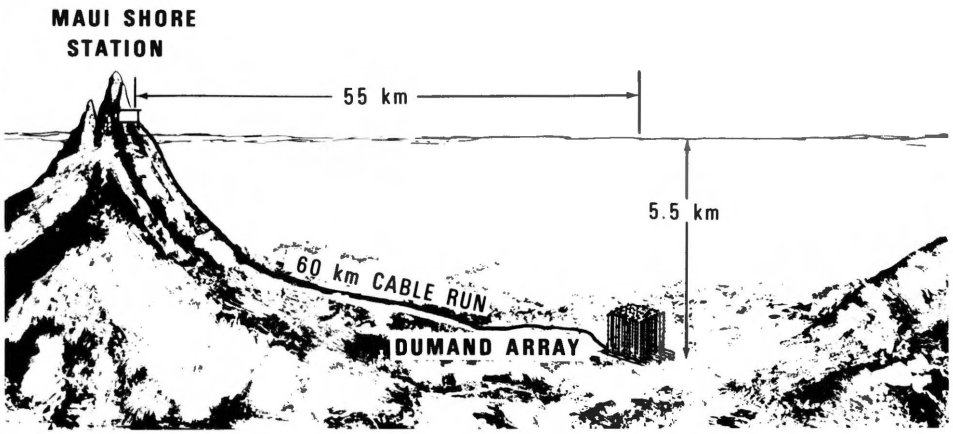
The Institute of Geophysics and Planetary Physics (IGPP) is a University of California systemwide institute with branches at Scripps Institution and the campuses at Los Angeles, Riverside, and Davis. The institute at La Jolla is intimately related to Scripps Institution through their geographical proximity, and more importantly, through their common scientific interests.

Dr. James N. Brune continued his cooperative seismic research project in Mexico, used physical models to understand earthquake strong motion, and analyzed new data pertaining to earthquake source mechanism. A project in cooperation with the Institute of Engineering of the University of Mexico, Mexico City, to deploy an array of strong motion seismographs in northwestern Mexico was continued. A study of S-wave attenuation in the earth's mantle was completed. With graduate student Alejandro Nava, a study of the structure of the Baja California Peninsula was continued using data from the July 1975, Piño Solo earthquake and the November 4, 1976, Panga earthquake. With Dr. Brian E. Tucker and graduate student Jerry L. King, digital seismic recorders are being used in the Garm Region, USSR, to study earthquake source spectra in cooperation with Russian investigators. With Drs. Gerald A. Frazier and Ralph J. Archuleta, and Stephen H. Hartzell and Steven M. Day, graduate students, studies were continued on the source mechanism of earthquakes, especially related to earthquake hazard. Focus of the study was on predicting earthquake strong motion for use in designing sensitive structures such as nuclear reactors.

Dr. Hugh Bradner continued his work with offshore earthquake studies via sonobuoys, and modified the Fanning Island station to monitor possible local earthquakes. He has worked extensively on Deep Undersea Muon and Neutrino Detection (DUMAND), including acoustic signals produced by high energy accelerator particles in water. Graduate student Mark R. Legg has continued seismicity studies at plate boundaries and in southern California borderlands. Graduate student Robert S. Howard has continued studies of hyperbaric pulmonary physiology and decompression. Alan L. Higgins, UC San Diego graduate student, has conducted studies of wave-filtering methods.

Sir Edward C. Bullard has spent most of the year studying the disposal of nuclear waste; this is a joint project of the Jet Propulsion Laboratory, California Institute of Technology, and Scripps Institution. The problem is not merely to find a way of storing waste, but to relate the amount and properties of the waste to other features of the fuel cycle.

Dr. J. Freeman Gilbert's research during the past year has been devoted to studies of 1) dissipation of energy radiated by earthquakes; 2) estimation of attenuation parameters at low frequen-



Above is an artist's conception of a large acoustic and optical array for DUMAND. High-energy cosmic ray neutrinos would require very large detectors to give useful counting rates. The acoustic and optical transparency of the ocean makes it uniquely useful for an array of detectors covering as much as one km³. In addition, the seawater above a deep array serves as an absorber of background particles. This new approach of using the ocean for studying astrophysics is a cooperative, multiuniversity effort now headquartered at Scripps.

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cies; 3) unmasking high-Q modes in spectra; 4) the effect of attenuation on eigenfunctions; 5) efficient construction of synthetic seismograms; 6) procedures for the retrieval of earthquake source mechanisms from low-frequency spectra; 7) improved methods of resolving split multiplets, and 8) the expansion of the Project IDA (International Deployment of Accelerometers) network. Principal collaborators have been Dr. Jonathan Berger and Dr. Raymond P. Buland. Dr. Buland also has been working with Dr. Thomas H. Jordan on 1) evaluating the effectiveness of long-period pure path experiments in the presence of multipathing (by numerical modeling), and 2) inverting free oscillation data for simple upper mantle lateral variations.

Dr. Berger continued the direction of Piñon Flat Geophysical Observatory, near Palm Springs, studying the seismotectonics of southern California. In cooperation with Dr. Gilbert and Dr. William E. Farrell, UC Berkeley, stations of the Project IDA very long-period seismic network have been established in Ñaña, Peru; Canberra, Australia; Sutherland, Republic of South Africa; Halifax, Nova Scotia; Piñon Flat, California; Garm, Tajikistan, USSR; Rarotonga, Cook Islands, and Brasília, Brazil. During 1977-78 stations are planned for Fairbanks, Alaska, and Oahu, Hawaii; McMurdo Sound, Antarctica; Sakhalin Island, USSR, and Zaria, Nigeria.

Dr. Archuleta has continued his studies of earthquake-caused near-field ground motion, using numerical modeling. With Day, he has simulated the 1966 Parkfield (central California) earthquake as a dynamic rupture within a geologically-layered medium. With Hartzell and Dr. Brune, he has examined both the far-field and near-field Fourier spectra of the particle displacement.

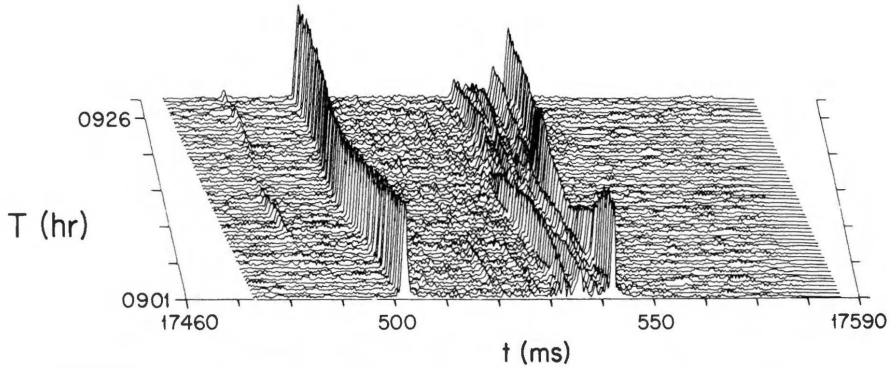
Dr. Frazier has been developing finite element techniques for numerically simulating earthquakes in order to learn more about earthquake processes and potentially hazardous ground motions. Through the combined efforts of Drs. Frazier and Archuleta and Day, 3-D finite element models have proven credible for reproducing analytical and laboratory results for earthquake-like slip along a dynamically spreading shear fracture. The numerical studies have provided new insight on the focusing of seismic energy in the direction of rupture propagation, the amplification of ground motion over confined sedimentary basins, and the modification of ground motion caused by the presence of civil structures.

Dr. Robert L. Parker, working with Dr. Roger J. Banks, a Cecil H. and Ida M. Green scholar, discovered that the isostatic response function of the United States was best explained by the inclusion of an elastic lithosphere, and that local compensation could effectively be ruled out. Dr. Parker and Marcia McNutt, a graduate student, found, however, that this was not the case for Australia, the explanation for the difference being an evolution of the isostatic mechanism with time, caused by slow relaxation of elastic stresses.

Dr. Geoffrey J. Daniell, a visiting Green scholar, devoted some time to determining the statistical parameters of signals from magnetometers lowered into Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) holes. This work, done with Dr. Parker, will affect proposed experiments by the Deep Sea Drilling Project. Dr. Bruce A. Hobbs, a Green scholar, worked mainly on electromagnetic induction in the moon; he was able to prove that commonly used values of the solar wind parameters are inconsistent with the electromagnetic data. Dr. Kenneth C. Macdonald, a Green scholar, studied theoretical models of fault patterns on oceanic spreading centers. He and Dr. William A. Prothero, UC Santa Barbara, were involved with deployment of ocean-bottom seismometer capsules on the Gorda Rise spreading center for studies of microearthquake seismicity on a slowly spreading ridge crest. Analysis of the above data is still underway. Dr. Prothero continued to analyze ocean-bottom seismic data from Elenerth Expedition, off the coast of Mexico.

Dr. John H. Woodhouse, Cambridge University, England, has been developing asymptotic methods for use in seismology. The principal results developing asymptotic methods for use in seismology. The principal results are (high frequency) asymptotic formulae for elastodynamic propagator matrices in flat and spherical earth models. One application has been in the determination of the asymptotic distribution of the earth's normal mode eigenfrequencies, for both toroidal and spheroidal modes and for all phase velocities. An application to the fast computation of synthetic seismograms is proceeding in collaboration with Dr. John A. Orcutt and Jan D. Garmany, graduate student. Dr. Woodhouse, in collaboration with Dr. Francis A. Dahlen, Princeton University, New Jersey, has completed a theoretical study on the perturbation and splitting of the earth's eigenfrequencies because of a general perturbation of a spherically symmetric earth model, including the effects of anisotrophy non-hydrostatic prestress, rotation, and asphericity, together with the effects arising from perturbations of solid-solid and solid-fluid boundaries within the earth.

Dr. George E. Backus extended the definitions of total mass, center of mass, and moment of inertia to tensor fields, and used these extensions to obtain descriptions of the shapes of localized seismic sources from observation of their seismic glut moment tensors of degrees zero, one, and two. He also showed how to use certain reasonable



Artist's conception of an ocean acoustic experiment shows acoustic arrivals at 25-km range from pulses transmitted at 30-second intervals at t=0. Horizontal axis is travel time t; vertical axis is clock time T. First large arrival at 17,502 msec is from purely refracted ray path that travels down into the ocean from the source and has turning point at about 1,500-m depth. Its simplicity reflects relative lack of fine structure in deep ocean. Cluster of arrivals occurring about 40 msec later are from a number of ray paths that travel upward from source and have turning points near 200-m depth. Multiplicity of depths originates from sound speed perturbations caused by fine structure in upper ocean.

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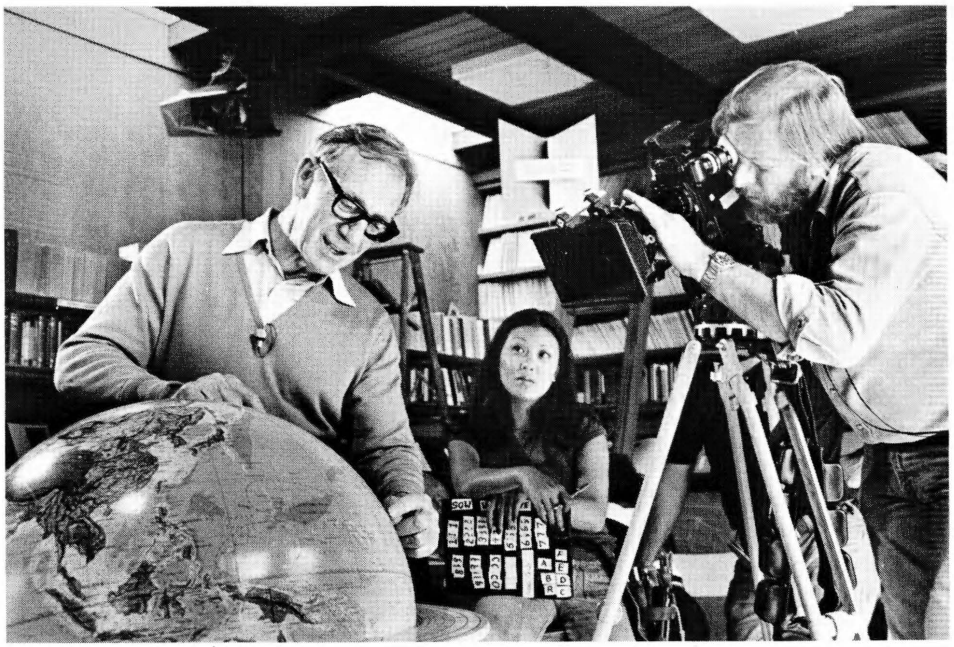
assumptions about the physics and geometry of a seismic source to obtain these glut moments from the force moments of degrees zero, one, and two; the latter are measurable, and, in general, the former are not.

The comparison by Dr. Richard A. Haubrich of Chandler wobble with the earthquake excitation series derived by Drs. Richard O'Connell and Adam Dziewonski, Harvard University, Massachusetts, shows no significant coherence between the two and suggests that earthquakes account for less than 25 percent of the Chandler wobble variance. Further investigation of maximum likelihood spectrum estimation techniques shows that results significantly depend on the specific estimate of the finite data set covariance.

The small-angle infrared scattering system designed by Dr. Ralph H. Lovberg to detect density fluctuations in thermonuclear fusion plasmas has been moved to UC Los Angeles and installed on the "Microtor" machine, a small-scale toroidal plasma generator. Initial experiments show that instabilities of the drift-wave type are of unexpectedly low magnitude in this system. During the coming year, this diagnostic procedure will be applied to the UC Los Angeles "Macrotor" device, which is more representative of state-of-the-art fusion research systems.

In physical oceanography, Drs. Walter H. Munk, Gordon O. Williams, and Peter F. Worcester and Bernard D. Zetler have continued their work on acoustic ocean monitoring. The results of a ship-to-ship operation have been analyzed by Dr. Worcester; upper and lower paths are well separated, and estimated relative currents along these two paths based on the difference in opposite transmission times give quite reasonable results. The precision of these measurements is potentially very high. Most of the effort this year is being expended in preparing for an experiment between moored sensors, to be undertaken in January 1978, in partnership with Scripps Institution's Marine Physical Laboratory and Woods Hole Oceanographic Institution, Massachusetts. The mid-water, neutrally buoyant capsule is being modified to include a CTD (Chemical/Temperature/Depth) instrument and an acoustic current meter, both designed by Neil Brown, Instrument Systems, Inc., Falmouth, Massachusetts. The current meter is to give the relative drift between the capsule and the instrument package below. Measurements of capsule descent during a summer experiment at Lake Tahoe, California, in 1975, have been analyzed jointly with Dr. James L. Cairns, La Spezia, Italy. They have given insight into a rather complex dynamics of a neutrally buoyant capsule. It is thought that an understanding of this dynamics will be helpful in an experiment in which the capsule is in a neutrally buoyant mode. Computations continue on large-scale subtidal fluctuations, cross-correlating subsurface pressures ("detided" sea level plus atmospheric pressure) at Bermuda, Azores, and Iceland. Those obtained from a numerical model use surface pressures and resulting winds as an input. The modeling is being done at the National Oceanic and Atmospheric Administration Geophysical Fluid Dynamics Laboratory, Princeton University. Computed and measured oscillations are of the same magnitude and show similar frequency structure, but the two records do not resemble one another closely in detail. Dr. C. Henry McComas is examining third-



Dr. Walter H. Munk uses world globe to discuss movements of waves across Pacific Ocean during filming for British Broadcasting Corporation's (BBC) Open University course in oceanography. Several Scripps scientists are participating in course, which may be offered to Californians under joint sponsorship of the BBC/Open University and UC extension programs. Cameraman Bryan Anderson and Tomiko Russell recorded session in reading room of Institute of Geophysics and Planetary Physics.

order spectra as an indicator of nonlinear interactions and the resultant transfer of energy within the oceanic internal wave field.

Dr. John W. Miles continued his research on nonlinear waves. He developed approximate results for propagation of a solitary wave in a channel of gradually varying breadth and depth; these results have been tentatively confirmed in laboratory tests by postdoctoral fellow Dr. Wallace K. Melville and UC San Diego graduate student Peter Chang. He also developed a nonlinear ray theory (analogous to that of geometrical optics) for solitary-wave propagation along coastlines. He is currently working on the inverse-scattering theory of nonlinear wave evolution with special emphasis on its relation to the linear theory of relatively long waves. Linear theory is not uniformly valid for large time or distance and fails to predict the existence of solitary waves, which may evolve in consequence of even very weak nonlinearity. Dr. Melville also has been planning experiments to test the theoretical predictions of solitary wave reflection at a wall. Preliminary flow-visualization experiments have been carried out in the ripple tank at the Department of Civil Engineering, UC Berkeley. He is continuing to work on problems of air-sea interaction, modeling the coupling among the wind, the wind-drift, and small breaking waves.

Drs. Myrl C. Hendershott and Richard L. Salmon and graduate student Paola Rizzoli continued to study large-scale ocean flow as turbulent flow. Dr. Salmon used turbulence theory to explain a generation of numerical simulations of two layer quasi-geostrophic flow; such mechanisms as baroclinic instability, occlusion, and the cascade of energy to large scales emerged naturally from the theory. Rizzoli and Dr. Hendershott looked for circumstances under which turbulence theory could not apply. Rizzoli constructed a model system in which nonlinear solutions of permanent form exist; their stability is now under study. Michael E. Parke, graduate student, and Dr. Hendershott developed a method for solving Laplace's tide equations with inclusion of ocean self attraction and solid earth loading. Parke has produced new global maps of the M2 tide.

Dr. Robert H. Stewart worked with National Aeronautics and Space Administration on the development of the SEASAT-A (oceanographic satellite) due to be launched in May 1978, and continued his work of using HF radio waves to study the sea surface. At present, working with Stanford University, California, he is attempting to use radio signals to measure the current shear in the upper few meters of the sea surface and to relate this to wind stress.

Dr. Kenneth M. Watson, UC Berkeley visiting scientist, studied the transport of energy within the ocean internal wave field. The Garrett-Munk exponential Väisälä profile and the WKB (Wentzel-Kramers-Brillouin) approximation were used to obtain the linear wave modes. Transfer of energy was studied using triad wave interaction.

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 and the planet's supply of organic and mineral materials, to harness energy from the sea, and to extend knowledge about other marine 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 facilities on the Davis and San Diego campuses of the University of California are administered from Scripps by John D. Isaacs, director. Advising the director on policy and research plans are an advisory council and an executive committee. The advisory council, staffed by public members appointed by the president of the university, is chaired by Scripps director Dr. William A. Nierenberg; the executive committee is staffed by faculty members.

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

Marine Food Chain Research

The Food Chain Research Group is a multidisciplinary group of investigators conducting research on the ecology and trophodynamics of the organisms comprising the lower levels of the marine planktonic food webs. Principal research emphasis is on the elucidation of biochemical and physiological bases of interactions among planktonic organisms and with their environment; and the manner in which these interactions regulate the flow of matter and energy through major trophic pathways.

The research approach combines field studies – designed to identify and quantitate natural populations and to characterize their physicochemical environments – with laboratory studies of ecologically significant biochemical and physiological activities of these organisms.

One FCRG field program includes a series of quarterly cruises in the Southern California Bight to examine the distribution patterns and standing stocks of plankton in relation to circulation patterns and seawater chemistry. One objective of the field work is to develop means of assessing the effects of energy production on the coastal pelagic ecosystems; such as, the use of seawater for cooling purposes in power-generating stations.

A second major field program in which several FCRG members are participating is the Controlled Ecosystem Pollution Experiment (CEPEX) being carried out in Saanich Inlet, British Columbia. The objective of CEPEX is to assess the effects of chemical and physical perturbations on the stability of pelagic marine food-webs. FCRG members are also working on the Ross Ice Shelf Project (RISP), examining the food webs below and around the antarctic ice shelf.

Drs. Angelo F. Carlucci and Farooq Azam are studying the trophic role of bacterioplankton in the food webs of natural and stressed coastal marine ecosystems. Dr. Carlucci, using microautoradiography, finds that as much as 50-80 percent of bacteria in waters off southern California are metabolically active. This is consistent with Dr. Azam's observations. He used size-fractionation techniques to find that free-living bacteria in the waters are metabolically active and are responsible for the metabolism of the major portion of dissolved organic matter. Dr. Carlucci continues to study the low-nutrient bacteria by examining the membrane transport systems for dissolved organic compounds in these organisms. Dr. Azam's CEPEX studies of bacterial populations subjected to mercury pollution ($1\mu g\ 1^{-1} Hg^{2+}$) indicate rapid selection for Hg-resistant form, which are also multiple-drug re-

sistant; these resistant bacteria are able to volatilize added Hg^{2+} as Hg.

Dr. John R. Beers's studies of microplankton in the central gyre of the North Pacific Ocean indicate they are of major importance as primary producers. Dr. Beers has continued to coordinate FCRG's efforts to develop a cine-holocamera to record behavioral activities of plankton. Dr. Beers is also studying the dynamics of microzooplankton in polluted ecosystems in conjunction with the CEPEX program.

Dr. Richard W. Eppley is investigating the vertical distribution of phytoplankton and plant nutrients in southern California coastal waters. A subsurface "chlorophyll maximum" layer is a persistent feature, sometimes possessing a unique phytoplankton species assemblage; the possible ecological significance of the layer is being explored. Dr. Eppley's laboratory studies on nanoplankton are designed to examine the physiology and growth characteristics of these important primary producers.

Dr. Osmund Holm-Hansen and associates find in their studies of the adenylate energy charge (EC) that adenine nucleotide distribution in marine algae is similar to other metabolically active cells and tissue and that EC can be used as an indicator of the bioenergetic state and growth status of marine phytoplankton. Their studies of quantum efficiency of phytoplankton reveal a lower efficiency in the surface layer caused probably by photoinhibition and photorespiration.

Dr. Michael M. Mullin has investigated the longshore distribution of plankton in the Southern California Bight by taking samples simultaneously from two ships spaced various distances apart. The degree of similarity in biomass and species composition between samples, as a function of distance between them, is used to describe the spatial pattern of the plankton assemblage.

Dr. Peter M. Williams is studying the composition of dissolved organic matter in coastal and deep-sea environments, in order to determine its role in bacterial heterotrophic activity and pollutant transfer mechanisms. He is also continuing his studies of the natural radiocarbon activity of marine organic matter to achieve a better understanding of the cycling of organic carbon in the oceans.

Sea Grant College Program at Scripps

The University of California Sea Grant College Program, administered by IMR, is headquartered at Scripps. Policy guidance for the program is vested in the IMR Advisory Council; administrative advice and program review rest with the IMR Executive Subcommittee for Sea Grant.

Sea Grant fulfills its mission of fostering the wise utilization of the resources of the sea and the defense against its hazards through support of 57 projects and 74 trainees on California campuses. Sea Grant carries out its objectives through research, education, training, and public service. A brief description of Scripps Sea Grant College projects follows. More detailed summaries are included elsewhere in this *SIO Annual Report.*

The "Ocean Education for the Public," project under Donald W. Wilkie, in collaboration with the Vaughan Aquarium-Museum staff and facilities, has involved 58,000 students in its group-education program on campus and in San Diego County schools and hospitals. Two other main activities during the year were 1) A Symposium for Teachers on the Behavior and Ecology of Fishes of California and the Gulf of California, and 2) a successful pilot expedition to study the nearshore ecology of marine life in the La Paz area of the gulf; this cleared the way for further expeditions.

Several projects dealt with the physical processes in the coastal environment, with the objective of applying this knowledge to coastal planning. The Shelf And Shore (SAS) system that has been developed provides essentially continuous and accurate wave data for such planning.

"Coastal Wetlands Management: Opening of Coastal Lagoons by Sand Fluidization," under Dr. Douglas L. Inman and Charles E. Nordstrom, is a feasibility study of duct-flow fluidization as a method for maintaining a stable lagoon channel at Los Peñasquitos Lagoon in San Diego County.

"Studies Toward the Optimal Management and Environmental Effects of Sea Urchin Fisheries," a study under Dr. Paul K. Dayton and Dr. Joseph H. Connell, UC Santa Barbara, aims to determine the important population parameters necessary for managing a sustained-yield fishery of the red sea-urchin, *Strongylocentrotus franciscanus,* and to protect it from over exploitation.

"The Social and Political Systems of the Tuna Fleets of San Diego and Ensenada: Their Place in International Cooperation and Competition for Marine Resources," is a comparative study of two fleets that use almost indentical equipment and draw, to a great extent, on the same labor pool yet function under different conditions of ownership, management, labor contracts, and government-industry relations. This study is directed by Drs. Frederick Bailey and Michael K. Orbach, National Marine Fisheries Service.

"Seaweed Products: Applications in Algae Control, Mariculture, and Agriculture," a study under Dr. William H.

Pumping equipment used in feasibility study of duct-flow fluidization as method of fluidizing and maintaining a stable lagoon entrance channel to Los Peñasquitos Lagoon in San Diego County. Work was part of a Sea Grant research project carried out by Dr. Douglas L. Inman and Charles E. Nordstrom, of the Shore Processes Study Group.

Graduate student James W. Stork emerges after a successful test dive wearing a breath heater and humidifier, a device developed by Stephen E. Suess, Foundation for Ocean Research, La Jolla, California, for SCUBA divers. Using about one percent hydrogen in the air tank and an oxidation catalyst, the device provides warm, moist air to the diver. It has been tested in the ocean and in laboratory tanks with encouraging results.

Stephen E. Suess

Unique launching of a model wave pump by a U.S. Marine helicopter from Kaneohe Bay, Hawaii, marked one of the Institute of Marine Resources' tests of a float attached to a 92-m-long pipe (portion of which is shown in photograph). Research indicated the pump, with its 5-cm-diameter pipe, magnified the pressure head more than 20 times. A by-product of operating this type of wave pump could be the fertilization of surface waters, provided the pipe is long enough to reach the entrained deep waters, which are rich in nutrients. Idea for such a wave-energy converter was that of John D. Isaacs. Dr. Gerald L. Wick and David Castel built and tested the converter under sponsorship of the State of Hawaii and its Natural Energy Laboratory.

U.S. Navy

Fenical, has concluded the initial exploration of the application of certain toxic marine products in algae control, in aquaculture disease control, and as insecticides and herbicides. Two patentable results were obtained. In one case, a compound found naturally in some red seaweeds of the family Rhodomelacea, when mixed with existing herbicides, eliminated the "wilt" effects normally observed with herbicide treatment. In the other case, elatol, a compound that can be extracted from various species of the red seaweed *Laurencia*, was found to induce precocious metamorphosis in insects, leading to their death within a few hours. Thus, a new method of insect control may have been discovered.

Dr. D. John Faulkner has continued work on his program, "Marine Natural Products Chemistry of Fouling Organisms." He is screening marine natural products, especially those from fouling organisms, and certain synthetic analogues against pathogenic marine bacteria.

Drs. Ralph A. Lewin and Fenical are aiming their study, "Tissue Culture of *Macrocystis* and Related Seaweeds of Economic Importance," at applying cell tissue-culture methods in the commercial raising of alginate-producing algae. Whereas wild-grown *Macrocystis* is the only abundant local source of alginates, the product varies in quality, consistency, and availability. Tissue culture may well represent a reliable source of algin-containing cells from other brown seaweeds, possibly yielding different products or increased yields.

Isaacs and Dr. Gerald L. Wick and Dr. Kurt Spiegler, UC Berkeley, are working on an intercampus venture, "Power from Salinity Gradients." This program is designed to tap the large amount of potential energy existing at the interface between waters of differing salinity. The magnitudes and locations of salinity power were evaluated, particularly in the United States and adjacent territory. Work on pressure-retarded osmosis, on the modified Claude process, and on reverse electrodialysis was continued, with special emphasis on the behavior of membranes at high pressures and salinities.

"Geology, Faulting, and Related Sea-Cliff Erosion, San Dieguito River to Carlsbad, San Diego County, California," is a study under the direction of Dr. Francis P. Shepard and Gerald G. Kuhn. They are collecting information on the geology, faulting, and related sea-cliff erosion in northern San Diego County since the 1880s. The results of this project will aid residents, developers, and community planners.

Additional Activities

During the past year IMR has been directing attention toward dealing with the energy problem in this country. IMR has been engaged in research on two important energy possibilities: ocean wave energy and salinity gradient energy.

Dr. Wick and David Castel, under sponsorship of the State of Hawaii and its Natural Energy Laboratory, built a wave-energy converter and tested it off Kaneohe Bay, Oahu. The device, conceived by Isaacs, is called the "wave pump," and consists of a 92-m-long pipe hung from a float, with a check valve at the submerged end. Water is lifted through the pipe by wave action into an accumulator tank from which it can be released through a turbine. In this way the wave pump is capable of amplifying the water head of the waves by a factor of 10-20.

In the test the pump was moored 5 km off the north shore of Oahu in 183 m of water. The float supported three

flexible polyethylene pipes, two 36 mm and one 56 mm in diameter. Hawaii lies in the tradewind zone. However, only mild seas of 6-second waves at 90-120 cm high were encountered. The wave pump generated 225 watts of mechanical power; that is, it converted about 25 percent of the wave energy that it intercepted. For immediate applications as a power source for instrumented weather buoys or research buoys, the wave pump may already be economically competitive with other sources. Large diameter pipes would provide proportionately larger amounts of power.

Salinity gradient energy is an unusual source of energy. It is manifest by the osmotic pressure difference between two solutions of different salt concentrations. For example, where fresh water flows into the ocean the osmotic pressure difference is 24 atm, equivalent to the pressure of a water column 238 m high. Calculations by Dr. Wick show that this resource is probably the most energetic of the marine power sources. In a further example, salt domes in the Gulf of Mexico theoretically harbor more energy in their salt than in the gas and oil they contain. Dr. Wick has been examining two means of extracting the energy – one based on the osmotic pressure difference using semipermeable membranes, and the other based on vapor pressure differences using the mass flow of the vapor between two solutions as the source of power.

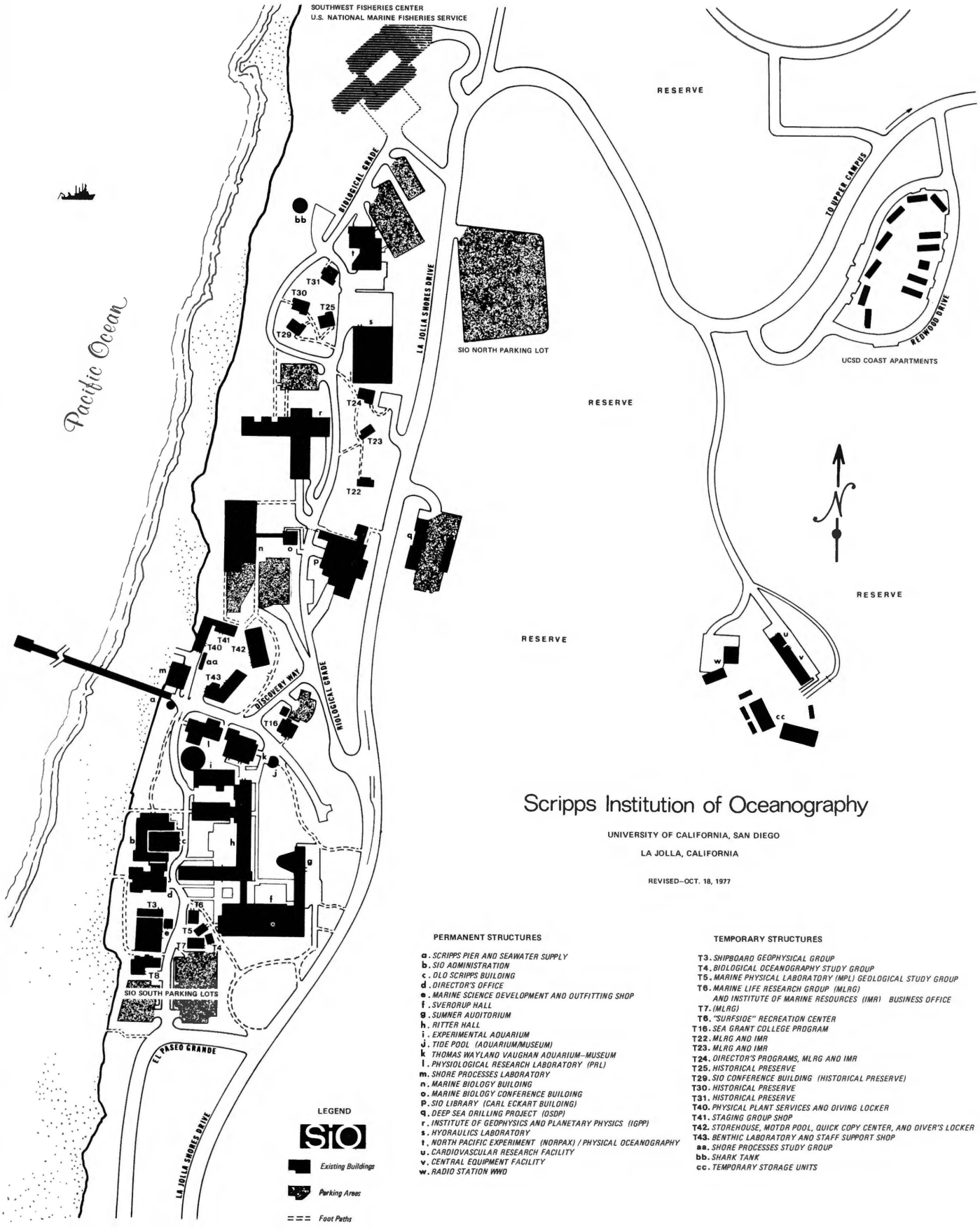
Several graduate student projects were carried out by IMR, with the support of the Foundation for Ocean Research, La Jolla. Steven L. Costa is completing studies of anisotropic sand transport in tidal inlets, a phenomenon that may lead to an inexpensive, effective means of clearing harbor mouths. James W. Stork has been accumulating additional support for the thesis that automobile traffic in the United States may be partially responsible for the dramatic increase of tornadoes in the last 25 years. He has also been testing an undersea, electrical-potential, anomaly detector. It has been used to follow internal waves and is presently being employed to map the discharge from submarine sewage outfalls.

Paul F. Tooby, graduate student, is continuing studies into the interaction of suspended particles with ocean turbulence. According to his research, particles can be trapped in small eddies and remain in suspension much longer than might be assumed from their sinking speed. Stephen Suess has been testing a heating device for SCUBA divers. Using about one percent hydrogen in the air tank and an oxidation catalyst, the device provides warm, moist air to the diver. It has been tested in the ocean and in laboratory tanks with very encouraging results.

Gail Bergman, UC San Diego student, is beginning a study of the interaction of tunas with porpoises in order to understand the population dynamics of these species. Graduate student Robert R. Ando has been investigating the fine-scale distribution of particulate matter near the thermocline. David Sheres, graduate student, has been investigating the properties of waves under high acceleration in his "tempest in a rotating teacup" experiment. He is also exploring the possibility of measuring ocean currents by detecting their interaction with ocean waves.

Francisco V. Vidal, graduate student, has been studying thermophilic bacteria obtained from an offshore hot spring near Punta Banda in Baja California. These studies led him to collect "slime" from the condensers of Encina power plant at Carlsbad, California, to test for thermophilic bacteria as the possible agent responsible for the attenuation of heat exchange in the condensers. Graduate student Victor M. Vidal has been examining the properties of rocks and water around the hot spring near Punta Banda. Studies of the metalliferous deposits and of the gas and water emerging from the hot spring provide valuable clues about its origin and possible utilization.

The institute publishes the *IMR Biennial Report,* which is available on request. In addition to describing the research undertaken within IMR, that report lists progress and technical reports for limited distribution in the *IMR Reference Series, q.v.,* and handbooks and charts for purchase in the *IMR Technical Report Series.*



Scripps Institution of Oceanography

UNIVERSITY OF CALIFORNIA, SAN DIEGO

LA JOLLA, CALIFORNIA

REVISED–OCT. 18, 1977

PERMANENT STRUCTURES

a. *SCRIPPS PIER AND SEAWATER SUPPLY*
b. *SIO ADMINISTRATION*
c. *OLO SCRIPPS BUILDING*
d. *DIRECTOR'S OFFICE*
e. *MARINE SCIENCE DEVELOPMENT AND OUTFITTING SHOP*
f. *SVERDRUP HALL*
g. *SUMNER AUDITORIUM*
h. *RITTER HALL*
i. *EXPERIMENTAL AQUARIUM*
j. *TIDE POOL (AQUARIUM/MUSEUM)*
k. *THOMAS WAYLAND VAUGHAN AQUARIUM–MUSEUM*
l. *PHYSIOLOGICAL RESEARCH LABORATORY (PRL)*
m. *SHORE PROCESSES LABORATORY*
n. *MARINE BIOLOGY BUILDING*
o. *MARINE BIOLOGY CONFERENCE BUILDING*
P. *SIO LIBRARY (CARL ECKART BUILDING)*
q. *DEEP SEA DRILLING PROJECT (OSDP)*
r. *INSTITUTE OF GEOPHYSICS AND PLANETARY PHYSICS (IGPP)*
s. *HYDRAULICS LABORATORY*
t. *NORTH PACIFIC EXPERIMENT (NORPAX) / PHYSICAL OCEANOGRAPHY*
u. *CARDIOVASCULAR RESEARCH FACILITY*
v. *CENTRAL EQUIPMENT FACILITY*
w. *RADIO STATION WWD*

TEMPORARY STRUCTURES

T3. *SHIPBOARD GEOPHYSICAL GROUP*
T4. *BIOLOGICAL OCEANOGRAPHY STUDY GROUP*
T5. *MARINE PHYSICAL LABORATORY (MPL) GEOLOGICAL STUDY GROUP*
T6. *MARINE LIFE RESEARCH GROUP (MLRG) AND INSTITUTE OF MARINE RESOURCES (IMR) BUSINESS OFFICE*
T7. *(MLRG)*
T8. *"SURFSIDE" RECREATION CENTER*
T16. *SEA GRANT COLLEGE PROGRAM*
T22. *MLRG AND IMR*
T23. *MLRG AND IMR*
T24. *DIRECTOR'S PROGRAMS, MLRG AND IMR*
T25. *HISTORICAL PRESERVE*
T29. *SIO CONFERENCE BUILDING (HISTORICAL PRESERVE)*
T30. *HISTORICAL PRESERVE*
T31. *HISTORICAL PRESERVE*
T40. *PHYSICAL PLANT SERVICES AND DIVING LOCKER*
T41. *STAGING GROUP SHOP*
T42. *STOREHOUSE, MOTOR POOL, QUICK COPY CENTER, AND DIVER'S LOCKER*
T43. *BENTHIC LABORATORY AND STAFF SUPPORT SHOP*
aa. *SHORE PROCESSES STUDY GROUP*
bb. *SHARK TANK*
cc. *TEMPORARY STORAGE UNITS*

SHORE FACILITIES AND COLLECTIONS

Facilities

Thomas Wayland Vaughan Aquarium-Museum (k). The aquarium-museum is devoted to increasing 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 services are also provided through responses to written, telephone, and face-to-face inquiries.

The staff, assisted by approximately 65 volunteer docents, conducts a manifold educational program. This year, through the major program, more than 58,000 students in educational groups toured the aquarium-museum. 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 careers in marine biology, ichthyology, and other aquarium-related fields. Sea Grant College Program funds support a full-time coordinator for educational programs.

Aquarium-museum research involves marine animal maintenance systems, fish coloration, and fish disease. Through the aquarium's collecting facility, several thousand specimens are gathered each year for Scripps scientists. During 1975-76 additional facilities for chilling seawater were added to the aquarium system. There are now two cold-water tanks, 10°C, with a combined volume of 6,800*l*.

Although admission to the aquarium-museum is free, voluntary contributions from many of the more than 383,000 yearly visitors provide significant financial support. The aquarium-museum is open to the public daily.

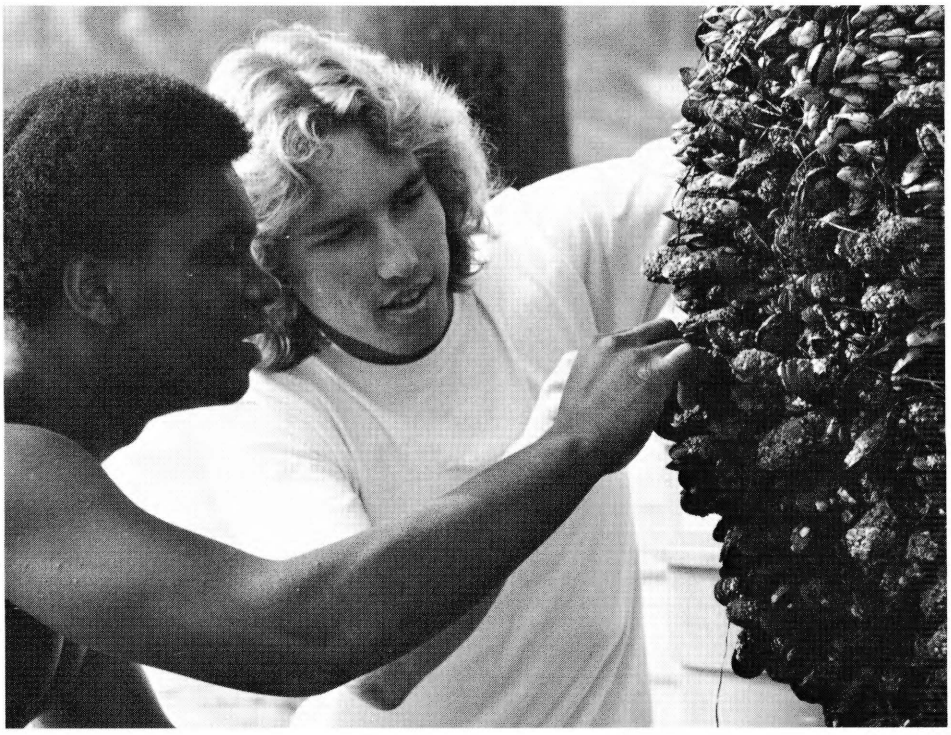
The aquarium-museum bookshop specializes in oceanographic literature, and selections vary from highly technical and scientific works to a variety of children's books and general-interest materials.

Analytical Facility (f) and (h). The facility provides 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 $1x10^{-12}$ 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 minicomputer for data handling; carbon-dioxide analyzer for sample carbon and carbonate content in terms of carbon dioxide; and 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. Two Siemens electron microscopes, together with freeze-etching 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 (u). 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 support of physiological research.

Diving Facility (T40). The diving program is housed in two separate facilities. One contains the mechanical portion of the program; *i.e.*, air compressors, filters, air-storage bank, diver air-cylinder storage, and SCUBA regulator repair. A diver wet equipment storage locker area is located in another building, along with shower and dressing facilities.

Scripps's scientific diver-training program, the oldest of its type in the country, trains more than 70 scientists and technicians annually. Through this training in the use of SCUBA as a scientific tool, they may obtain data available by no other means. These classes are generally limited to UC San Diego personnel with the need to work or study



Youth from the Upward Bound enrichment program from the Los Angeles area examine mussels and barnacles during their training in a summer aquarists' project at the aquarium-museum.

underwater; however, federal, state, and local government employees may be admitted by special permission. There are currently 140 faculty, staff, and students who make an average of 4,000 scientific and technical dives per year. These dives are completed in all the oceans of the world, including the Arctic. During the past ten years Scripps divers have amassed more than 60,000 accident-free scientific and training dives.

Electron Microprobe Laboratory (f). 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 (i). Used by faculty, research staff, and graduate students for various studies of living plants and animals, this aquarium is provided with ambient and chilled seawater, and is equipped with five rooms for controlled environmental studies, 20 tanks, and nine seawater tables.

Hydraulics Laboratory (s). 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 concrete basin; a 10x1x1-m fluidizing channel; three sand-storage and calibration tanks each 4 m high by 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 incorporate servo systems and can be computer or magnetic-tape 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. The City of San Diego has designated the surrounding tidal and shoal waters be retained in a natural condition.

Nothing so attracted the 58,000 school children who visited Vaughan Aquarium-Museum during the year as a close inspection of marine life in the onshore tide pool.

Photo by Don Bartletti, courtesy of *Oceanside Blade-Tribune*

Marine Physical Laboratory Calibration Center (Off campus, in San Diego). This facility, which was a branch of the National Oceanographic Instrumentation Center until July 1, 1976, is equipped to calibrate oceanographic instrumentation for governmental and non-governmental research. It concentrated mainly on STD/CTD equipment, mechanical bathythermographs, and laboratory salinometers.

Marine Science Development and Outfitting Shop (e). This shop is equipped with precision tools and has a staff of toolmakers and diemakers who design, develop, and fabricate research equipment and instrumentation in support of the various laboratories at Scripps, the Southwest Fisheries Center of the National Marine Fisheries Service, UC San Diego, the Scripps fleet, and other educational and governmental organizations throughout the United States. The shop carries an extensive stock of fabrication materials and provides forklift service with a 6,804-kg-capacity unit.

Mass Spectrographic Equipment (f) and (h). Nine mass spectrometers are available, including two 15-cm, Nier-type spectrometers, and one 6-cm Micromass instrument 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; a small, portable, helium mass spectrometer for field use; and a 3-cm mass spectrometer for stable isotope tracer measurements.

Mt. Soledad Radioisotope Laboratory (3 km south of Scripps campus near the top of Mt. Soledad). This laboratory's location provides isolation from other research areas where relatively large amounts of radioactivity are used and thus insures the contamination-free setting required for the study of radioactive species at the extremely low levels normally encountered in the natural environment. The laboratory provides low background counting systems for the detection of alpha-, beta-, and gamma-emitting radionuclides; chemical facilities for the processing of biological, sediment, and seawater samples; and a high precision, computer-controlled flame spectrophotometer for the study of natural cesium and other alkaline metals in the ocean. Research at the laboratory is directed toward understanding the input into the environment and subsequent behavior of radionu-

clides from military, industrial, and research sources. In addition, a significant effort is now being directed toward expanding the scope of the laboratory to make use of naturally occurring radionuclides as traces of processes occurring in marine, geologic, and hydrologic systems.

Petrological Laboratory (h). This facility provides thin-sectioning, microprobe sample preparation, and rock-surfacing services to staff and students of Scripps and associated research groups. All types of submarine and subaerial igneous, metamorphic, and sedimentary materials in various states of lithification are prepared here by plastic-vacuum techniques and other types of impregnations for microscopic study. The laboratory is administered through the Geological Research Division.

Physiological Research Laboratory Pool Facility (l). 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" 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 is being used for respiration and energy consumption studies on swimming and diving sea lions and the effects of crude oil coating on the metabolism of sea otters.

Radio Station WWD (w). Licensed to the National Marine Fisheries Service and operated by personnel from Scripps's Nimitz Marine Facility, Station WWD provides communications services to both organizations as well as to other governmental and institutional ships and to the Deep Sea Drilling Project's D/V *Glomar Challenger;* and weather advisories to the fishing fleet and to 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 eight hours a day on Saturday, Sunday, and holidays.

San Vicente Lake Calibration Facility (48 km from Scripps). 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.

Scripps Library (p). The library's outstanding collections in oceanography, marine biology, and undersea technology complement its impressive store of oceanographic information. In addition to monographs and serials in mathematics, physics, chemistry, geology, and zoology, the main collection includes extensive expedition literature. As of June 30, 1977, the library housed 116,080 bound volumes; 27,562 maps and charts; 20,611 reprints; 27,387 documents, reports, and translations; and 4,648 pieces of microcopy. The Documents/Reports/Translations Collection is comprised of a nucleus of technical reports and memoranda published by Scripps and supplemented by reports and translations from other educational, governmental, and industrial institutions involved in marine research. The Map and Chart Collection includes atlases, nautical charts, and geological 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, and numerous accounts and journals of famous voyages of discovery.

Scripps Pier (a). 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.

Seawater System (a). Pumps located on Scripps Pier deliver seawater to the laboratories and aquaria of Scripps and the Southwest Fisheries Center. The seawater system utilizes two high-speed sandfilters and two concrete storage tanks having a total capacity of 439,060*l*. Delivery capacity is 5,300*l* per minute. Another storage tank will be added in 1977-78, increasing the total capacity to 658,590*l*.

Shipboard Computer Group (h). 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 on campus in Ritter Hall and in the NORPAX Building.

The IBM 1800 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

Ben D. Bush, Marine Science Development and Outfitting Shop toolmaker and diemaker (foreground), mills chrome-alloy, tempered-steel tubing for core-cutting device used by Deep Sea Drilling Project's D/V* Glomar Challenger, *as toolmaker and diemaker Matthew A. Unwin adjusts blade guide on band saw for his next job.

Jackie Janke

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), 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 tape for return to Scripps, and they may be processed, correlated by time or position, and displayed numerically or graphically, at sea and ashore.

A digital seismic-reflection system, under development and first tested in 1975-76 as a joint venture of the Shipboard Geophysical Group and Shipboard Computer Groups, is capable of sampling up to 24 analog signals at 1-kHz sample rate (24-kHz total) and recording them on a high-density digital magnetic tape. The sampling and recording capability can be applied to any digital or analog time series, but will be used primarily with acoustic geophysical transducers.

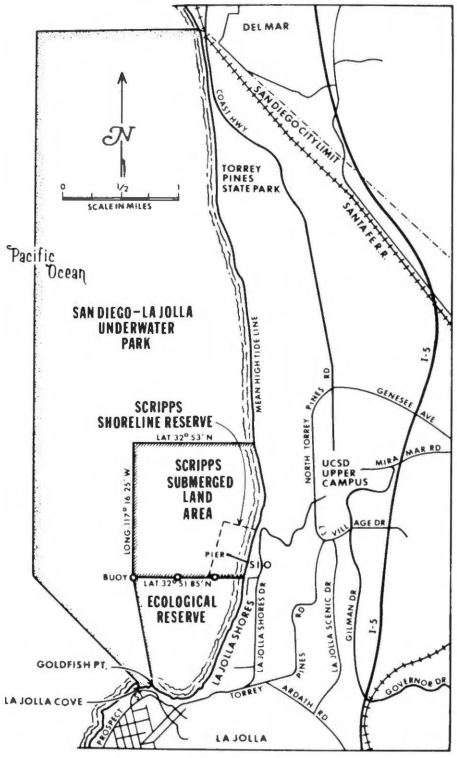
Shore Processes Laboratory (m). This laboratory is the research facility investigation of the nearshore environment. This is a multipurpose building with a data processing laboratory, electronics laboratory, and general work area. The lower level houses a sedimentation laboratory, calibration laboratory, and mechanical shop. The data processing laboratory includes 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 minicomputer equipped with a disk storage unit, digital tape recorders, a paper tape recorder, graphic plotter, and CRT terminal. The building also houses an extensive library of reference material on coastal-zone processes and a collection of nearshore sediment samples.

Underwater Research Areas (see 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 Reserve (also identified as "The San Diego Marine Life Refuge" CFG 10902), which consists of a 100-acre tract of seashore and ocean including the area of the beach together with the waters of the ocean to a line 300 m seaward of the lowest low tide. It extends a north-south distance of 850 m between the southern end of the Scripps seawall and the northern property line of the National Marine Fisheries Service. All marine plants and invertebrates are protected for research purposes and may be collected only with permits issued by the University of California through the Vaughan Aquarium-Museum. This area has been used extensively for research by staff members and graduate students and, in addition, is used for instructional purposes by outside institutions as well as 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 that is reserved for installation of oceanographic instruments by the Navy and

Janet B. Pulsifer examines a specimen from the marine vertebrate collection which has been cleared and stained so it is transparent and has a fuchsia-red fossil appearance.



URA Map

Scripps. This area is currently unmarked.

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 often acts as guides. The reserve, established in 1972, has shown measurable return to its original pristine condition. 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

Benthic Invertebrates (k). The collection contains some 28,000 lots of specimens sorted into major taxonomic groups such as Crustacea, Echinodermata, and Mollusca. All are cataloged with collection data and over 35 percent are identified according to species. Specimens are available for study to qualified students and researchers.

Deep Sea Drilling Project Core Repository (q). Scripps houses the West Coast Repository for cores collected by DSDP. 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 the Lamont-Doherty Geological Observatory, Columbia University, New York.) Samples from these cores are made available to qualified researchers throughout the world under policies established by NSF.

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

Geological Data Center (h). Most of the geological/geophysical data collected by Scripps vessels while underway are processed and archived at this location. Navigation, depth, and magnetics are computer-processed for entry into the digital data base and for production of cruise reports and plots. Seismic profiler records are microfilmed, blown back at reduced scale, and reassembled by geographic area to permit rapid retrieval and evaluation. Index track charts, with overlays of the various data types, contain approximately one million nautical miles of Scripps cruises, as well as tracks of DSDP's *Glomar Challenger.* The data center also maintains a multidisciplinary index of all samples and measurements made on major Scripps cruises.

Marine Invertebrates (Zooplankton Collection, h and 16 km southeast of Scripps). In this collection are nearly 64,000 documented zooplankton samples; of these more than 21,000 are from special collections and expeditions and some 1,250 from Isaacs-Kidd midwater trawls. Included are sorted specimens and identified collections of major taxonomic groups, including the adult cephalopoda. Yearly additions to the collection average between 1,000 and 1,500 samples. Most samples are supplemented by meteorological, hydrographic, physical, and chemical data.

Marine Vertebrates (Fish Collection, h). Approximately 3,000 cataloged species of marine fishes and in excess of 1.5 million specimens are in this collection. Added in 1976 were 399 collections of bathypelagic and shore fishes.

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 Chief, Pacific Tide Party, National Ocean Survey, 1801 Fairview Avenue East, Seattle, Washington 98102.

Temperature and salinity records taken daily since 1916 from Scripps Pier, and records for various years from other California shore stations, along with data from more than 20,000 hydrographic casts from Scripps cruises, are managed by the Data Collection and Processing Group of the Marine Life Research Group. Summaries of the shore-station data, issued annually, are available upon request to Data Collection and Processing Group, Scripps Institution of Oceanography, S-001, La Jolla, California 92093.

PUBLICATIONS

Introduction

The publications of the Scripps Institution are the end product of the faculty's and staff's research. These publications are highly technical, ranging from long taxonomic descriptions to short data reports. Scripps publications are distributed by subscriptions, exchanges, or government contracts.

Below is a complete listing of the Scripps Institution of Oceanography publications for fiscal 1977. Detailed availability information is included for each series.

Bulletin

In *Bulletin of the Scripps Institution of Oceanography* are published 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.

Cited below are the three most recent volumes:

V.21 PERRIN, William F. Variation of Spotted and Spinner Porpoise (Genus Stenella) in the Eastern Tropical Pacific and Hawaii. 206p.

V.22 RENZ, G. W. The Distribution and Ecology of Radiolaria in the Central Pacific: Plankton and Surface Sediments. 267p.

V.23 WORMUTH, John H. The Biogeography and Numerical Taxonomy of the Oegopsid Squid Family Ommastrephidae in the Pacific Ocean. 91p.

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 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.

These 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 institutions or libraries interested in acquiring atlases please write to: Dr. Abraham Fleminger, Scripps Institution of Oceanography, A-001, La Jolla, California 92093.

The Atlas issued this year is listed below.

No. 24 BRINTON, E. and J. G. WYLLIE. Distributional Atlas of Euphausiid Growth Stages Off Southern California, 1953 Through 1956. 320p.

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: University of California, San Diego, Library Gifts and Exchange Department, C-075, La Jolla, California 92093.

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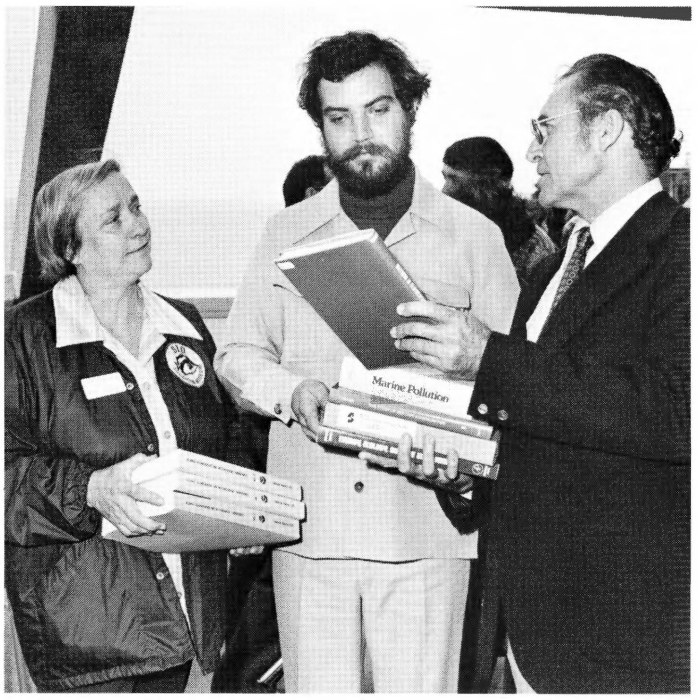

Dr. Robert L. Fisher, associate director (right), and Mrs. Patricia A. Kampmann give scientific books and journals to Francisco Aguilar Ruiz, director of Escuela Superiór de Ciencias Marinas (ESCM), Universidad Autónoma de Baja California (the marine science campus of the state university of Baja California), in Ensenada, Mexico. The gift from People-to-People was presented during annual Cinco de Mayo visit to Scripps of nearly 70 students and faculty members from ESCM. The activity was coordinated by People-to-People, of which Mrs. Kampmann is chairman, a women's international-relations interest group of UC San Diego Oceanids, whose membership is open to all women associated with UC San Diego.

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Two Chinese scientists from Taiwan, Drs. Chi-wu Wang (left) and Shien-Siu Shu (second from right), met with Scripps scientists during a campus visit in August 1976. They are shown conferring with Drs. Harmon Craig (right) and Yu-chia Chung in the Isotope Laboratory. Dr. Shu is chairman of the National Science Council (NSC), Republic of China, and president, National Tsing-hwa University; Dr. Wang is director of the International Cooperation Section of NSC. Their visit was part of a tour of U.S. institutions.

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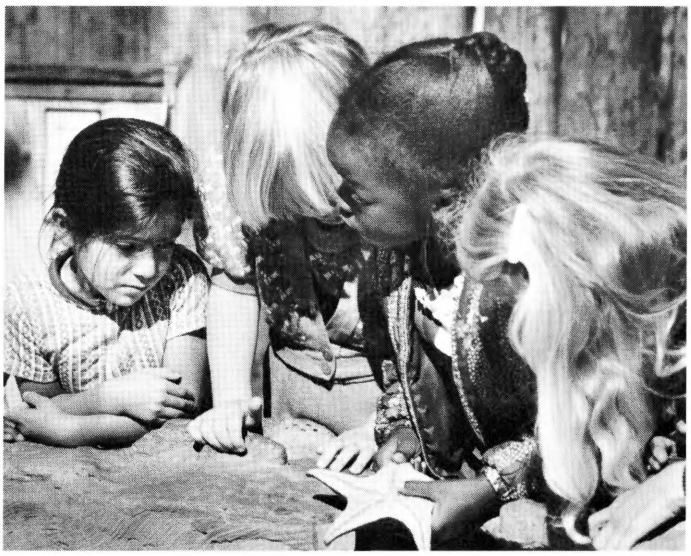

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Before speaking at the institution on the subject, "Science: International Cooperation," Dr. Isidor Isaac Rabi, 78 (left), Nobel laureate in physics whose career as a scientist and statesman spans nearly half a century, chats briefly with Director Nierenberg (center) and Dr. Walter H. Munk. Dr. Rabi is university professor emeritus of Columbia University, where Dr. Nierenberg studied for his doctorate under Dr. Rabi.

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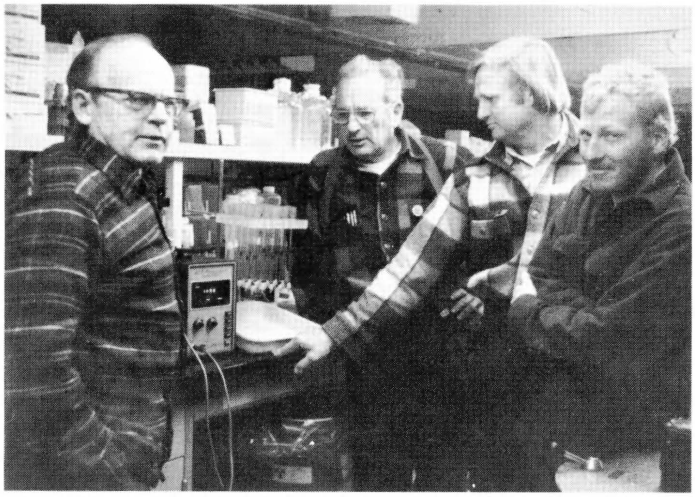
Dr. Elizabeth L. Venrick



Three scientists and an economist-educator visited a National Science Foundation (NSF) biology laboratory at McMurdo Sound, Antarctica, in January 1977. Two of them, members of the National Science Board (NSB), had been invited to McMurdo Sound to examine scientific research activities of the U.S. Antarctic Research Program. NSB is the policy-making body of NSF.

The two NSB members are Dr. Glenn Campbell (left), regent of the University of California and director of the Hoover Institution on War, Revolution, and Peace, Stanford University, and Director Nierenberg (second from left). Second from right is Dr. Osmund Holm-Hansen, who was at McMurdo Sound studying distribution and biochemical characteristics of microbial cells in Antarctic water masses. His work was part of the international, NSF-sponsored, Ross Ice Shelf Project, an extensive program to investigate the history and biology of the ice shelf and the environment beneath it. At right is Scripps graduate student John S. Oliver. He "wintered over" in the area, studying the benthic ecology of Antarctica. The other three returned home shortly after visiting the area.

Eklund Biological Laboratory, McMurdo Sound, Antarctica

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	Charles S. Cox	Marine Life Research Group	Physical Oceanography
	Harmon Craig	Geological Research Division	Geochemistry and Oceanography
	Joseph R. Curray	Geological Research Division	Marine Geology
	Russ E. Davis	Ocean Research Division	Physical Oceanography
	Paul K. Dayton	Ocean Research Division/ Sea Grant College Program	Biological Oceanography
	Sir George E. R. Deacon	Ocean Research Division	Physical Oceanography
	Georges G. Desaedeleer	Geological Research Division	Chemistry
	Walter J. Desmond	Marine Biology Research Division	Biology
	Arthur L. DeVries	Physiological Research Laboratory	Physiology
+	Patrick DeWever	Geological Research Division	Geology
+	Robert R. Dickson	Ocean Research Division	Macro-Air-Sea Interaction in Atlantic and Pacific Sectors and Their Relationship
	Robert S. Dietz	Geological Research Division	Geology
	Allan F. Divis	Geological Research Division	Geology
	LeRoy M. Dorman	Geological Research Division	Geophysics
	Patricia S. Doyle	Geological Research Division	Paleontology
*	Seibert Q. Duntley	Visibility Laboratory	Physics
	Phillip Dustan	Marine Biology Research Division	Biology
	Robert C. Eaton	Neurobiology Unit	Neurobiology
	A. E. J. Engel	Geological Research Division	Geology
	Celeste Gilpin Engel	Geological Research Division	Chemistry
	Theodore Enns	Marine Biology Research Division	Physiology
	James T. Enright	Ocean Research Division	Biological Oceanography
	David Epel	Marine Biology Research Division	Marine Biology
	Richard W. Eppley	Institute of Marine Resources	Biological Oceanography
†*	Edward W. Fager	Ocean Research Division	Biological Oceanography
	D. John Faulkner	Ocean Research Division/ Sea Grant Program	Marine Natural Products Chemistry
	Albert S. Feng	Neurobiology Unit	Neurobiology
	William H. Fenical	Institute of Marine Resources/ Sea Grant Program	Chemistry
	Felipe G. Fernandez	Institute of Marine Resources	Zooplankton Ecology
	Jean H. Filloux	Ocean Research Division	Physical Oceanography
	Robert C. Finkel	Ocean Research Division	Marine Chemistry
	Frederick H. Fisher	Marine Physical Laboratory	Marine Physics
	Robert L. Fisher	Geological Research Division/ Ship Operations and Marine Technical Support	Marine Geology
	Raymond W. Fitzgerald	Geological Research Division	X-ray Physics
	Abraham Fleminger	Scientific Collections/ Marine Life Research Group	Marine Geology
	Theodore R. Folsom	Ocean Research Division	Physical Oceanography
	Theodore D. Foster	Ocean Research Division	Physical Oceanography
*	Denis L. Fox	Marine Biology Research Division	Marine Biology
	Jeffery D. Frautschy	Director's Office SIO/ Sea Grant Program/ Institute of Marine Resources	Marine Technology/ Shore Processes/ Geophysics/ Water Quality/ Coastal Zone Management

	Jane Zaiser Frazer	Geological Research Division	Numerical Analysis
	Gerald A. Frazier	AMES/ Institute of Geophysics and Planetary Physics	Geophysics
	Carl A. Friehe	AMES/ Ocean Research Division	Ocean Turbulence
	Robert Galambos	Neurobiology Unit	Neurobiology
	Walter F. Garey	Physiological Research Laboratory	Physiology
	Carl H. Gibson	AMES/ Sea Grant College Program	Fluid Dynamics
	Joris M. T. M. Gieskes	Ocean Research Division	Marine Chemistry
+	Eliezer Gilat	Institute of Marine Resources	Zoology
	J. Freeman Gilbert	Institute of Geophysics and Planetary Physics	Geophysics
	Edward D. Goldberg	Geological Research Division	Chemistry
	Daniel Goodman	Department SIO	Analytical Ecology
	Fritz W. Goro	Marine Biology Research Division	Marine Biology
	Jimmie L. Greenslate	Geological Research Division	Oceanography
	John J. Griffin	Geological Research Division	Mineralogy
	Roger Grismore	Ocean Research Division	Physics
	Robert T. Guza	Marine Life Research Group/ Ocean Research Division	Physical Oceanography
#	Edwin L. Hamilton	Geological Research Division	Geophysics
	Harold T. Hammel	Physiological Research Laboratory	Physiology
	James L. Harris	Visibility Laboratory	Optical Physics
	William G. Harrison	Institute of Marine Resources	Marine Ecology
	A. Baird Hastings	Neurobiology Unit	Biochemistry
	Richard A. Haubrich	Institute of Geophysics and Planetary Physics	Geophysics
	James W. Hawkins	Geological Research Division	Geology
	Francis T. Haxo	Marine Biology Research Division	Marine Botany
	Walter F. Heiligenberg	Ocean Research Division	Behavioral Physiology
	Edvard A. Hemmingsen	Physiological Research Laboratory	Physiology
	Myrl C. Hendershott	Ocean Research Division	Physical Oceanography
	Robert R. Hessler	Marine Life Research Group/ Marine Biology Research Division	Biological Oceanography
	Martin D. Higgs	Ocean Research Division	Chemistry
	Steven A. Hillyard	Neurobiology Unit	Neurobiology
	Bruce A. Hobbs	Cecil H. and Ida Green Scholar/ Institute of Geophysics and Planetary Physics	Geophysics
	Edmund S. Hobson	Marine Biology Research Division	Marine Biology
	Vernon F. Hodge	Geological Research Division	Chemistry
	Nicholas D. Holland	Marine Biology Research Division	Marine Biology
	James T. Hollibaugh	Institute of Marine Resources	Biology
	Osmund Holm-Hansen	Institute of Marine Resources	Marine Biology
*	Carl L. Hubbs	Marine Biology Research Division	Marine Biology
	Kuni Pfeffer Hulsemann	Marine Life Research Group	Zooplankton Taxonomy
	John P. Hunt	Institute of Marine Resources/ Geological Research Division	Earth Resources
#	John R. Hunter	Department SIO	Ichthyology
	Douglas L. Inman	Ocean Research Division	Physical Oceanography

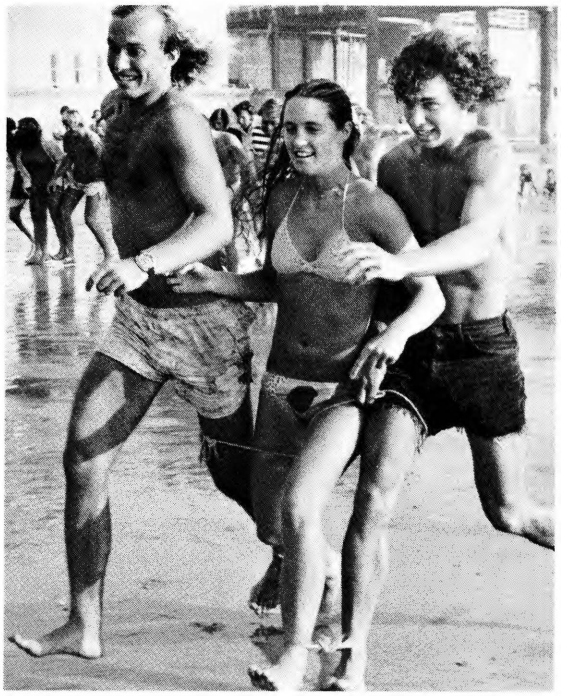
	John D. Isaacs	Institute of Marine Resources/ Marine Life Research Group	Oceanography
*	Martin W. Johnson	Marine Life Research Group	Marine Biology
	Roger N. Johnson	Marine Biology Research Division	Biochemistry
	Thomas H. Jordan	Geological Research Division	Geophysics
	James Joseph	Institute of Marine Resources	Marine Biology
	Daniel E. Karig	Marine Physical Laboratory	Tectonics of Marginal Seas Subduction Zone
	Miriam Kastner	Geological Research Division	Geology
	G. Thomas Kaye	Marine Physical Laboratory	Oceanography
	Charles D. Keeling	Ocean Research Division	Marine Chemistry
	John B. Keene	Geological Research Division	Geology
	Brian D. Keller	Ocean Research Division	Oceanography
	George J. Kenagy	Physiological Research Laboratory	Zoology
	Michael P. Kennedy	Geological Research Division	Geology
	Kern E. Kenyon	Ocean Research Division	Physical Oceanography
	Dale A. Kiefer	Marine Life Research Group	Marine Biology
+	Judith Tegger Kildow	Institute of Marine Resources/ Political Science	Resources Scientist
	John S. Killingley	Geological Research Division	Chemistry
+	Baruch Kimor	Institute of Marine Resources	Biology
	R. James Kirkpatrick	Deep Sea Drilling Project/ Geological Research Division	Geology
	Stanley A. Kling	Marine Life Research Group	Paleontology
	Margaret D. Knight	Marine Life Research Group	Biological Oceanography
	Robert A. Knox	Ocean Research Division	Oceanography
	Minoru Koide	Geological Research Division	Marine Chemistry
	Wilhelmus Kokke	Institute of Marine Resources	Theoretical Organic Chemistry
	Gerald L. Kooyman	Physiological Research Laboratory	Physiology
	Richard H. Krajcik	Institute of Geophysics and Planetary Physics	Physics
	Devendra Lal	Geological Research Division	Nuclear Geophysics
	Yves P. Lancelot	Geological Research Division	Marine Geology
	Michael R. Landry	Institute of Marine Resources	Biology
	G. David Lange	Neurobiology Unit	Neurobiology
	R. Edward Lange	Ocean Research Division	Physical Oceanography
	Francis L. LaQue	Marine Physical Laboratory	Chemical Engineering
	John C. LaRue	Ocean Research Division	Engineering
#	Reuben Lasker	Department SIO	Marine Biology
+	Mark L. Laudenslager	Physiological Research Laboratory	Physiological Psychology
	Lawrence A. Lawver	Marine Physical Laboratory	Geophysics
	Phung Le Cong	Institute of Geophysics and Planetary Physics	Physics
	Stuart A. Levison	Marine Physical Laboratory	Physical Chemistry
	Ralph A. Lewin	Marine Biology Research Division	Marine Biology
	Leonard N. Liebermann	Physics/ Marine Physical Laboratory	Physics
	Cinna Lomnitz	Geological Research Division	Geophysics
	Peter F. Lonsdale	Marine Physical Laboratory	Geology
	Ralph H. Lovberg	Physics/ Institute of Geophysics and Planetary Physics	Physics
	Carl D. Lowenstein	Marine Physical Laboratory	Marine Physics
	John E. Lupton	Geological Research Division	Physics

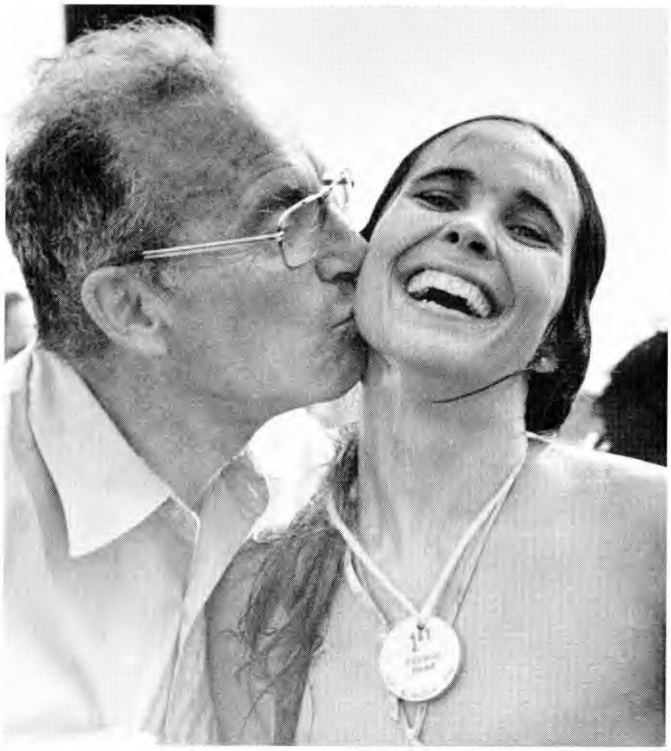
	Kenneth C. Macdonald	Cecil H. & Ida Green Scholar/ Institute of Geophysics and Planetary Physics/ Geological Research Division/ Marine Physical Laboratory	Geophysics
	J. Douglas Macdougall	Geological Research Division	Marine Geology
	Jacqueline Mammerickx	Geological Research Division	Geology
	Arnold Mantyla	Marine Life Research Group	Oceanography
	E. Roger Marchand	Neurobiology Unit	Neurobiology
	Patricia Masters	Ocean Research Division	Marine Chemistry
	Tetsuo Matsui	Marine Life Research Group	Biological Oceanography
	Jerry L. Matthews	Geological Research Division	Geology
	Edward D. McAlister	Marine Physical Laboratory	Physics
	C. Henry McComas III	Institute of Geophysics and Planetary Physics	Oceanography
+	Frank J. McEnroe	Department SIO	Marine Natural Products
	John A. McGowan	Marine Life Research Group	Biological Oceanography
	Charles W. Mehard	Marine Biology Research Division	Biochemistry
	Wallace K. Melville	Institute of Geophysics and Planetary Physics	Geophysics
	H. William Menard	Geological Research Division/ Institute of Marine Resources	Geology
	Charles J. Merdinger	Deputy Director	Civil Engineering
	Jason H. Middleton	Ocean Research Division	Oceanography
	Naja E. Mikkelson	Geological Research Division	Paleontology
	John W. Miles	AMES/ Institute of Geophysics and Planetary Physics	Geophysics/ Fluid Dynamics
	Stephen P. Miller	Marine Physical Laboratory	Geophysics
	David G. Moore	Deep Sea Drilling Project/ Geological Research Division	Geology
	Robert D. Moore	Institute of Geophysics and Planetary Physics	Geophysics
	Gerald B. Morris	Marine Physical Laboratory	Geophysics
	John D. Mudie	Marine Physical Laboratory/ Geological Research Division	Geophysics
	Michael M. Mullin	Institute of Marine Resources	Biological Oceanography
	Walter H. Munk	Institute of Geophysics and Planetary Physics/ Ocean Research Division	Geophysics
	Jerome Namias	Ocean Research Division	Long Range Weather Forecast/ Ocean-Atmosphere Interaction
	James H. Natland	Deep Sea Drilling Project/ Geological Research Division	Geology
	Kenneth H. Nealson	Marine Biology Research Division	Microbiology
	Judd C. Nevenzel	Marine Biology Research Division/ Physiological Research Laboratory	Biochemistry
	William A. Newman	Marine Biology Research Division/ Scientific Collections	Biological Oceanography
	William A. Nierenberg	Director	Physics
	David J. Nishioka	Marine Biology Research Division	Biology
	Charles E. Nordstrom	Ocean Research Division/ Sea Grant Program	Geology
+	Makoto Omori	Marine Life Research Group	Biology
	John A. Orcutt	Geological Research Division	Geophysics
	Benton B. Owen	Marine Physical Laboratory	Chemistry
	Frances L. Parker	Geological Research Division	Paleontology
	Robert L. Parker	Institute of Geophysics and Planetary Physics/ Ocean Research Division	Geophysics

	John S. Patton	Marine Biology Research Division	Marine Biology
	William C. Patzert	Marine Life Research Group	Oceanography
	Melvin N. A. Peterson	Deep Sea Drilling Project/ Geological Research Division	Marine Geology
	Fred B Phleger	Geological Research Division	Oceanography
	Robert Pinkel	Marine Physical Laboratory	Internal Waves
	William A. Prothero	Institute of Geophysics and Planetary Physics	Geophysics
*	Russell W. Raitt	Marine Physical Laboratory	Marine Geophysics
*	Norris W. Rakestraw	Ocean Research Division	Marine Chemistry
	Bindiganavale N. Ravi	Ocean Research Division	Chemistry
	Freda Hunt Reid	Institute of Marine Resources	Taxonomy
	Joseph L. Reid	Marine Life Research Group	Physical Oceanography
*	Roger R. Revelle	Director Emeritus/ Department SIO/ Political Science	Natural Resources/ Science and Public Policy
	William R. Riedel	Scientific Collections/ Geological Research Division	Marine Geology
	John O. Roads	Ocean Research Division	Meteorology
+	William M. Rosen	Institute of Marine Resources	Marine Chemistry
	Richard H. Rosenblatt	Marine Biology Research Division/ Scientific Collections	Marine Zoology
	Bruce R. Rosendahl	Geological Research Division	Geology
	Arnold Ross	Marine Biology Research Division	Invertebrate Paleontology
	Steven S. Rossi	Marine Biology Research Division	Biology
#	Brian J. Rothschild	Institute of Marine Resources/ Department SIO	Fisheries/ Population Dynamics
	Philip Rudnick	Marine Physical Laboratory	Physics
	Matthew H. Salisbury	Deep Sea Drilling Project	Geology
	Richard L. Salmon	Ocean Research Division	Oceanography
	Annika Berggren Sanfilippo	Geological Research Division	Paleontology
	Marston C. Sargent	Marine Life Research Group	Biological Oceanography
	J. F. Theodore Saur	Ocean Research Division	Oceanography
	Walter R. Schmitt	Marine Life Research Group	Marine Resources
*	Per F. Scholander	Physiological Research Laboratory	Physiology
	Richard A. Schwartzlose	Marine Life Research Group	Physical Oceanography
	John G. Sclater	Marine Physical Laboratory	Geophysics
	Robert W. Severance, Jr.	Ocean Research Division	Physical Oceanography
	Richard J. Seymour	Institute of Marine Resources	Oceanography
	Omar H. Shemdin	Ocean Research Division	Nearshore Processes
*	Francis P. Shepard	Geological Research Division	Submarine Geology
	George G. Shor, Jr.	Marine Physical Laboratory/ Sea Grant College Program	Marine Geophysics
	Donald E. Silva	Visibility Laboratory	Applied Physics
	John Sinkankas	Geological Research Division	Mineralogy
	Kenneth L. Smith	Marine Biology Research Division	Ecological Energetics of Deep-Sea Population and Communities
	Raymond C. Smith	Visibility Laboratory	Physics
	Stuart M. Smith	Ship Operations and Marine Technical Support	Submarine Geology
	Harold Solomon	Ocean Research Division	Oceanography
+	B. L. K. Somayajulu	Geological Research Division	Geochemistry
	George N. Somero	Marine Biology Research Division	Marine Biology
	Andrew Soutar	Marine Life Research Group	Paleontology
	Fred N. Spiess	Marine Physical Laboratory	Marine Physics
+	Martha O. Stallard	Institute of Marine Resources	Chemistry
	Robert E. Stevenson	Ocean Research Division	Space Oceanography
+	Joan Godsil Stewart	Institute of Marine Resources	Biology

	Robert H. Stewart	Ocean Research Division/ Institute of Geophysics and Planetary Physics	Oceanography
	Charles K. Stidd	Ocean Research Division	Meteorology
	James J. Sullivan	Sea Grant Program	Economics
	Mia J. Tegner	Ocean Research Division	Marine Biology
	Hans R. Thierstein	Geological Research Division	Geology
	William H. Thomas	Institute of Marine Resources	Microbiology
	Mizuki Tsuchiya	Institute of Marine Resources	Biological Oceanography
	Robert C. Tyce	Marine Physical Laboratory	Physics
	John E. Tyler	Visibility Laboratory	Physics
	John L. Usher	Deep Sea Drilling Project	Paleontology
*	Victor Vacquier	Marine Physical Laboratory	Geophysics
	Charles W. Van Atta	AMES/ Sea Grant College Program	Geophysical Fluid Dynamics
	William G. Van Dorn	Ocean Research Division	Physical Oceanography
	Elizabeth L. Venrick	Marine Life Research Group	Oceanography
	Edith S. Vincent	Geological Research Division	Nanofossil Micropaleontology
	Benjamin E. Volcani	Marine Biology Research Division	Marine Microbiology
+	Christopher C. von der Borch	Department SIO/ Geological Research Division	Geology
	Thomas G. Warner	Marine Biology Research Division	Chemistry
	Ray F. Weiss	Geological Research Division	Geochemistry
	Richard T. Wert	Ocean Research Division	Meteorology/ Data Processing
	Oscar E. Weser	Deep Sea Drilling Project	Marine Sedimentation
	Bruce J. West	Department SIO	Physics
*	Charles D. Wheelock	Institute of Marine Resources	Naval Architecture
	Fred N. White	Physiological Research Laboratory	Comparative Physiology
	Stanton M. White	Deep Sea Drilling Project	Sedimentology
	Warren B. White	Ocean Research Division	Oceanography
	Gerald L. Wick	Institute of Marine Resources	Physics
	Donald W. Wilkie	Aquarium-Museum	Marine Biology
	Gordon O. Williams	Institute of Geophysics and Planetary Physics	Geophysics
	Peter M. Williams	Institute of Marine Resources	Biological Oceanography
	Wayne H. Wilson	Visibility Laboratory	Hydrologic Optics
	Clinton D. Winant	Ocean Research Division/ Sea Grant College Program	Oceanography
	Edward L. Winterer	Geological Research Division	Geology
+	John H. Woodhouse	Institute of Geophysics and Planetary Physics	Geophysics
	Peter F. Worcester	Institute of Geophysics and Planetary Physics	Oceanography
	A. Aristides Yayanos	Physiological Research Laboratory	Physiology
	Bernard D. Zetler	Institute of Geophysics and Planetary Physics	Oceanography
*	Claude E. ZoBell	Marine Biology Research Division	Marine Microbiology

\# Adjunct Professor Series
* Emeritus
\+ Visiting/ Postdoctoral Scholar
† Deceased





Things get pretty hectic during the Scripps family picnic, until it's time to acknowledge a winner, that is. At top left, Denise Shows and Brooks McKinney (foreground) place second in wheelbarrow race. Among those in the four-legged race (above) are Scott Steinert, Laura Cass, and Peter Lathin (left to right), all tied up together. And Kim Devonald gets resounding buss from Director Nierenberg.

Photos by Robert Vallera, Jr.
courtesy of *La Jolla Light*

Appendix A

ASSOCIATE DIRECTORS
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G. G. Shor, Jr.
F. N. Spiess

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W. A. Nierenberg

DEPUTY DIRECTOR
C. J. Merdinger

ASSISTANT DIRECTORS
J. D. Frautschy
G. L. Matson

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GEOLOGICAL RESEARCH DIVISION
J. N. Brune/ J. R. Curray

MARINE BIOLOGY RESEARCH DIVISION
F. T. Haxo/ R. H. Rosenblatt

OCEAN RESEARCH DIVISION
C. S. Cox/ W. A. Newman

MARINE PHYSICAL LABORATORY
F. N. Spiess

PHYSIOLOGICAL RESEARCH LABORATORY
A. A. Benson/ F. N. White

VISIBILITY LABORATORY
S. Q. Duntley/ J. L. Harris

DEEP SEA DRILLING PROJECT
M. N. A. Peterson

MARINE LIFE RESEARCH GROUP
J. L. Reid

INSTRUCTION

GRADUATE DEPARTMENT OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY
F. N. Spiess/ M. M. Mullin, Chairman
M. M. Mullin/ M. C. Hendershott, Vice-Chairman

APPLIED OCEAN SCIENCES
C. D. Winant

BIOLOGICAL OCEANOGRAPHY
R. R. Hessler

GEOPHYSICS
R. L. Parker

MARINE BIOLOGY
G. N. Somero

MARINE CHEMISTRY
G. Arrhenius

GEOLOGICAL SCIENCES
E. L. Winterer/ H. W. Menard

PHYSICAL OCEANOGRAPHY
R. S. Arthur

TECHNICAL SUPPORT

SHIP OPERATIONS AND MARINE TECHNICAL SUPPORT
R. L. Fisher

NIMITZ MARINE FACILITY
P. S. Branson

MARINE TECHNOLOGY GROUP
J. L. Abbott

SHIP SCHEDULER
R. B. Haines

ALPHA HELIX PROGRAM OFFICE

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W. A. Newman

PLANKTONIC INVERTEBRATES
A. Fleminger

MARINE VERTEBRATES
R. H. Rosenblatt

GEOLOGICAL
W. R. Riedel

UC INSTITUTES

INSTITUTE OF GEOPHYSICS AND PLANETARY PHYSICS
W. H. Munk, Associate Director
J. N. Brune/ J. F. Gilbert, Associate Director

INSTITUTE OF MARINE RESOURCES
J. D. Isaacs, Director
Food Chain Research Group
Sea Grant College Program

PUBLIC SERVICE

AQUARIUM-MUSEUM
D. L. Wilkie

LIBRARY
W. J. Goff

PUBLIC AFFAIRS
R. N. Fuller

TECHNICAL PUBLICATIONS
K. K. Kuhns

Appendix B

SPONSORS OF RESEARCH AND GRADUATE INSTRUCTION

STATE:
State of California
Department of Fish and Game
Department of Navigation and Ocean Development

FEDERAL:
National Science Foundation
Department of the Navy
Office of Naval Research
Naval Supply Center
Naval Ocean Systems Center
Energy Research and Development Administration
Department of the Air Force
National Aeronautics and Space Administration
Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Department of Defense
Defense Mapping Agency
Department of the Interior
Geological Survey
Department of Health, Education, and Welfare

OTHER:
Alcoa Foundation
American Cancer Society
American Heart Association
American Metal Climax Foundation, Incorporated
AMOCO International Oil Company
ARCS Foundation
Atlantic Richfield Company
Atlantic Richfield Foundation
Stephen and Mary Birch Foundation, Incorporated
Chevron Oil Field Research Company
Cities Services Company
William L. Dowd Memorial Fund
EXXON Production Research Company
Foundation for Ocean Research
Cecil H. and Ida M. Green Foundation
Gulf Oil Corporation
The Helis Foundation
International Nickel Company
Kelco
Kennecott Copper Corporation
Kennecott Exploration, Incorporated
S. H. Kress Foundation
La Jolla Foundation for Earth Sciences
John B. McKee Fund
Mobil Oil Corporation
National Academy of Sciences
Navy League of San Francisco (Chester W. Nimitz Fund)
Occidental Petroleum
Ocean Management, Incorporated
Pacific Sierra Research Corporation
Elsa U. Pardee Foundation
Peterson-Silberman Fund
Helen Raitt Memorial Fund
Rockefeller Foundation
Science Applications, Incorporated
Ellen Browning Scripps Endowment Fund
Sea World Incorporated
G. D. Searle and Company
Shell Oil Company
Francis P. Shepard Foundation
A. P. Sloan Foundation
Société Nationale des Pétroles d'Aquitaine
Seth Sprague Foundation
Sun Oil Company
Texaco Incorporated
Union Oil Company
United States Steel Foundation, Incorporated
Van Camp Foundation
Westinghouse Electric Corporation

Appendix C

MAJOR AWARDS AND HONORS

Dr. Victor C. Anderson
Received Distinguished Public Service Award from U. S. Navy.

George Boehlert, graduate student
Named second annual recipient of the Carl L. Hubbs Sea World Fellowship in Marine Biology.

Sir Edward C. Bullard
Received Honorary Doctor of Science degree, University of East Anglia, England.

Dr. Albert E. J. Engel
Received Honorary Doctor of Science degree, University of Missouri.

Dr. Denis L. Fox
Elected Fellow of the Institute of Biology, London.

Dr. Carl L. Hubbs
Elected honorary member of the French Society of Ichthyology.
Dedication to him of the November issue of *Bulletin of the Southern California Academy of Sciences.* Dedication of the Carl and Laura Hubbs-Sea World Research Institute.

Dr. Douglas L. Inman
Received Distinguished Alumni Award from San Diego State University's Alumni Association.

John D. Isaacs
Elected to the National Academy of Engineering.
Received Award of Excellence from the University of California, San Diego Chancellor's Associates.

Dr. H. William Menard
Received the Francis P. Shepard Award from the Society of Economic Paleontologists and Mineralogists.

Dr. Walter H. Munk
Received the Professional Achievement Award from the University of California, Los Angeles.

Dr. Jerome Namias
Elected Fellow of the American Association for the Advancement of Science.

Dr. William A. Nierenberg
Appointed Senior Consultant to the Office of Science and Technology Policy, Washington, D. C.

Dr. Roger R. Revelle
Received the first University of California, San Diego, Alumnus of the Year Award.

Dr. Richard L. Salmon
Received the second annual Eckart Dissertation Prize from Scripps Institution of Oceanography, University of California, San Diego.

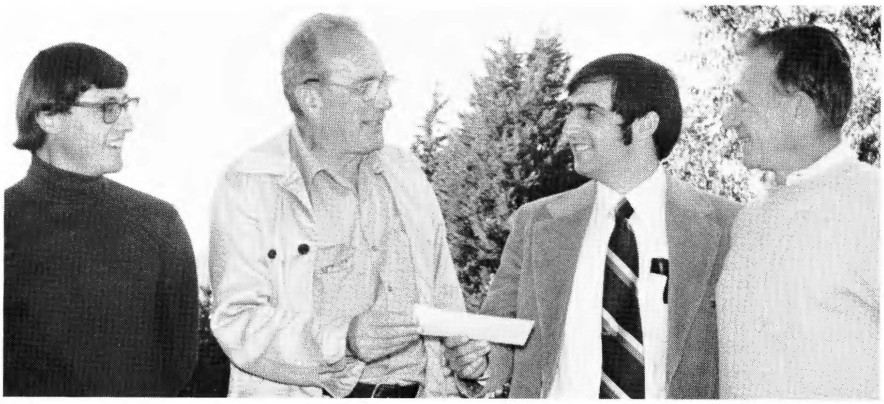
James R. Stewart
Received Outstanding Contribution to Diving Award from the National Association of Underwater Instructors. Received an award for Advance Diving Programs for 1976 from the Los Angeles Department of Parks and Recreation.
Appointed to San Diego-La Jolla Underwater Park Advisory Committee by San Diego City Council.

Dr. James J. Sullivan
Elected Chairman of the Council of Sea Grant Directors.

Dr. Elizabeth L. Venrick
Elected one of ten outstanding young citizens of 1976, by the San Diego Junior Chamber of Commerce. Received Headliner of the Year Award from the San Diego Press Club.

Bernard D. Zetler
Portrait added to display of distinguished oceanographers at National Ocean Survey, Rockville, Maryland.

Dr. Claude E. ZoBell
Appointed first Editor-in-Chief of *Geomicrobiology Journal.*



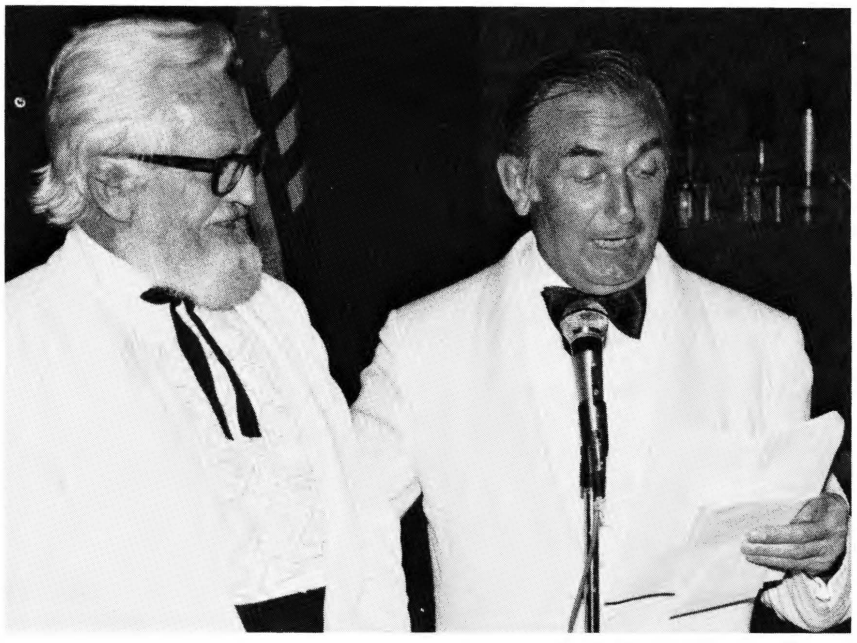
Director Nierenberg (center left) presents $1,000 check for Eckart Dissertation Prize to Dr. Richard L. Salmon, Scripps graduate and researcher at institution. Looking on are Dr. Walter H. Munk (right) and Dr. Myrl C. Hendershott, both of whom participated in special award seminar that featured a lecture by Dr. Salmon. Award commemorates the late Dr. Carl H. Eckart, who served as director of the Marine Physical Laboratory and of Scripps, professor of geophysics, and UC San Diego's first vice-chancellor for academic affairs.

Dr. Douglas L. Inman (right) receives Distinguished Alumni Award from San Diego State University Alumni Association, with Dr. Baylor Brooks making the presentation. Dr. Inman received his B.A. degree in physics from San Diego State University (SDSU) in 1942. He studied under Dr. Brooks, a professor of geology at SDSU from 1931-1966. Dr. Inman's advanced degrees are from Scripps Institution.

Photo courtesy of SDSU Alumni Association

At annual awards dinner of UC San Diego Chancellor's Associates, John D. Issacs (left) listens as Walter Zable, associates president, reads citation of organization's Award of Excellence to Issacs "for his contribution to community interaction."

Glasheen Graphics



Appendix D

RESEARCH VESSELS OF SCRIPPS INSTUTUTION OF OCEANOGRAPHY

	Alexander Agassiz*	Alpha Helix	Melville	Ellen B. Scripps	Thomas Washington	FLIP	ORB
Type:	light freight	oceanographic research (biological)	oceanographic research	offshore supply	oceanographic research	floating instrument platform	oceanographic research buoy
Hull:	steel	steel	steel	steel	steel	steel	steel
Year built:	1944	1965-1966	1969	1964-65	1965	1962	1968
Year acquired by Scripps:	1961	1966	1969	1965	1965	1962	1968
From whom acquired:	State Educational Agency for Surplus Property	National Science Foundation	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	U.S. Navy	University of California	U.S. Navy	U.S. Navy	U.S. Navy
Length (ft.):	180′	133′	245′	95′	209′	355′	69′
Beam (ft., in.):	32′	31′	46′	24′	39′5″	20′	45′
Draft (ft., in.):	10′	10′5½″	16′	6′	14′5″	11′/300′	fwd. 4′10½″ aft 5′4½″
Displacement: Tons (full):	869	512	2,075	234	1,362	1,500 (vertical)	325
Cruising speed:	10	10	10	9	11	varies[-1]	varies[-1]
Range (miles):	4,000	7,200	9,181	5,100	10,000	varies[-1]	varies[-1]
Endurance (days):	22	30	41	14	36	30	30
Crew:	16	12	19-20	5	19	6	5
Scientific party:	15	12	30	8	23	10	10

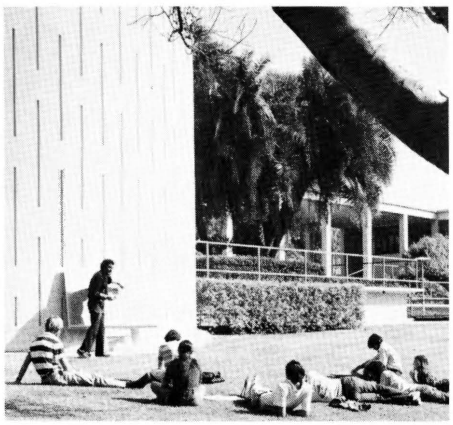
[-1] Depends upon towing vessel

Ships on inactive status: Gianna** and Dolphin

NOTE: For metric conversion, one foot equals 0.3048 meters; one nautical mile equals 1.835 kilometers; one pound equals 0.4536 kilograms; one short ton (2,000 pounds) equals 0.907 metric tons.

1976-77 Total days at sea: 1,200
1976-77 Nautical miles steamed: 105,276

* Sold to private buyer in November 1976
** Sold to private buyer in April 1977



Sumner Auditorium (left) and Sverdrup Hall (right) serve as a backdrop for a class in the sun. At start of 1976-77 academic year, 188 students were enrolled, of whom three received Master of Science degrees and 25 received Doctor of Philosophy degrees awarded by UC San Diego at year's end.

Appendix E

DOCTOR OF PHILOSOPHY DEGREES AWARDED IN 1976-77 WITH TITLES OF DISSERTATIONS

Earth Sciences

Ralph J. Archuleta, "Experimental and Numerical Three-Dimensional Simulations of Strike-Slip Earthquakes."

Rodey Batiza, "Oceanic Crustal Evolution: Evidence from the Petrology and Geochemistry of Isolated Oceanic Central Volcanoes."

Rex A. Couture, "Synthesis of Some Clay Minerals at 25°C; Palygorskite and Sepiolite in the Oceans."

James R. Herring, "Charcoal Fluxes into Cenozoic Sediments of the North Pacific."

John B. Keene, "The Distribution, Mineralogy, and Petrography of Biogenic and Authigenic Silica from the Pacific Basin."

Ian D. Reid, "The Rivera Plate: A Study in Seismology and Plate Tectonics."

George F. Sharman, "The Plate Tectonic Evolution of the Gulf of California."

Sharon A. Stonecipher, "Origin, Distribution and Diagenesis of Deep-Sea Clinoptilolite and Phillipsite."

Marine Biology

John E. Burris, "Photorespiration in Marine Plants."

David M. Gardiner, "Intraovarian Storage of Spermatozoa in the Viviparous Teleost *Cymatogaster aggregata* Gibbons (Perciformes: Embiotocidae)."

Everett E. Sinnett, "Pulmonary Circulation of the Harbor Seal, *Phoca vitulina*, Including a Comparison of Its Responsiveness to Hypoxia with that of the Dog."

Nancy W. Withers, "Biochemical and Physiological Studies on the Binucleate Marine Dinoflagellate, *Peridinium foliaceum* Stein."

Oceanography

Charles G. Adelseck, Jr., "Recent and late Pleistocene Sediments from the Eastern Equatorial Pacific Ocean: Sedimentation and Dissolution."

Raymond Lee Gordon III, "Internal Wave Climate Near the Coast of Northwest Africa during JOINT 1."

John F. Heinbokel, "Functional and Numerical Responses of Coastal Tintinnids: Implications for the Neritic Food Chain."

Greg Holloway, "Statistical Hydromechanics: Applications in Mesoscale Ocean Circulation."

Charles L. Johnson, "The Separation of Wave-Induced and Intrusive Oceanic Fine Structure."

Harold W. Lyons, "Seasonality in Central North Pacific Chaetognaths."

J. Murray McDonald, "Sediments and Structure of the Nicobar Fan, Northeast Indian Ocean."

Arne C. Mortensen, "Optimized System for High Resoltion Measurements of Oceanic Temperature and Velocity."

Eric Shulenberger, "Spatial and Associational Pattern in the Hyperiid Amphipod Assemblage of the North Pacific Central Gyre."

Michael M. Sinclair, "Phytoplankton Distributions in the Lower St. Lawrence Estuary."

Gerald G. Stock, "Modeling of Tides and Tidal Dissipation in the Gulf of California."

David E. Thistle, "Harpacticoid Copepods: A Problem in Deep-Sea Diversity Maintenance."

Peter F. Worcester, "Reciprocal Acoustic Transmission in a Mid-Ocean Environment."

MASTER OF SCIENCE DEGREES AWARDED IN 1976-77

Marine Biology

Victor Chow

Oceanography

Jan L. Hillson
Randall S. Jacobson

SIO GRADUATES 1976-77

Student Name and New Position

Charles G. Adelseck, Jr.
Assistant Research Geologist
Deep Sea Drilling Project–SIO

Ralph J. Archuleta
Postgraduate Research Geophysicist
Institute of Geophysics and Planetary Physics–SIO

Rodey Batiza
Assistant Professor
Washington University
St. Louis, Missouri

John E. Burris
Assistant Professor
Pennsylvania State University
University Park, Pennsylvania

Rex A. Couture
Postdoctoral Fellowship–SIO

David M. Gardiner
Assistant Professor
Occidental College
Los Angeles, California

Raymond Lee Gordon III
Postgraduate Research Oceanographer
Ocean Research Division–SIO

John F. Heinbokel
Chesapeake Bay Institute
Johns Hopkins University
Baltimore, Maryland

James R. Herring
Southern California Coastal Water Research Project
El Segundo, California

Greg Holloway
Advanced Study Program
National Center for Atmospheric Research
Boulder, Colorado

Charles L. Johnson
Postgraduate Research Oceanographer
Ocean Research Division–SIO

John B. Keene
Postdoctoral Fellowship
Université Paris–SUD
Paris, France

J. Murray McDonald
U.S. Navy Fleet Numerical Weather Central
Monterey, California

Arne C. Mortensen
EG&G Environmental Consultants
Waltham, Massachusetts

Ian D. Reid
Research School of Earth Sciences
Australian National University
Canberra, Australia

George F. Sharman
Assistant Professor
Texas A&M University
College Station, Texas

Eric Shulenberger
Biological Oceanography Program
Office of Naval Research
Bay St. Louis, Mississippi

Michael M. Sinclair
Assistant Professor
Université du Québec
Rimouski, Quebec, Canada

Everett E. Sinnett
Department of Physiology
Harvard School of Public Health
Boston, Massachusetts

Sharon A. Stonecipher
Marathon Oil Company
Littleton, Colorado

David E. Thistle
Assistant Professor
Florida State University
Tallahassee, Florida

Nancy W. Withers
Postdoctoral Fellowship
University of Liverpool
Liverpool, England

Peter F. Worcester
Postgraduate Research Geophysicist
Institute of Geophysics and Planetary Physics–SIO

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 Superintendant of Public Instruction
Donald G. Reithner
President of the Alumni Association of the University of California
Gene E. Pendergast, Jr.
Vice President of the Alumni Association of the University of California
David S. Saxon
President of the University

APPOINTED REGENTS

Edward W. Carter
Frederick G. Dutton
William K. Coblentz
DeWitt A. Higgs
Glenn Campbell
William French Smith
Robert O. Reynolds
Dean A. Watkins
Joseph A. Moore, Jr.
John H. Lawrence
William A. Wilson
Gregory Bateson
Vilma Martinez
Verne Orr
John Henning
Stanley K. Sheinbaum
Yoritada Wada
Michael B. Salerno

University of California student Regent Daryn Peeples feeds a fish to Trisha, a California sea lion under study at the Physiological Research Laboratory, during informal visit by regents to the institution in May 1977. Peeples and alumni Regents Earl Willens (left) and Charles Field (center) and Regent William A. Wilson (right) met with various faculty and staff members and toured Nimitz Marine Facility.

PRINCIPAL OFFICERS OF THE REGENTS

Donald L. Reidhaar
General Counsel
Owsley B. Hammond
Treasurer
Marjorie J. Woolman
Secretary

FACULTY REPRESENTATIVE TO THE BOARD OF REGENTS

John S. Galbraith

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—Agriculture and University Services
Lowell J. Paige
Special Assistant to the President for Governmental Relations
Dorothy E. Everett
Assistant President—Coordination and Review
David A. Wilson
Executive Assistant

OFFICERS EMERITI

Clark Kerr
President of the University, Emeritus, and Professor, Emeritus, of Business Administration
Charles J. Hitch
President of the University, Emeritus, and Professor, Emeritus, of Economics
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, Professor, Emeritus, of Agricultural Economics, and Agricultural Economist, Emeritus
Robert M. Underhill
Vice President, Emeritus, and Secretary and Treasurer of the Regents, Emeritus
Thomas J. Cunningham
General Counsel of The Regents, Emeritus
Frank L. Kidner
Vice President—Educational Relations, Emeritus, and Professor, Emeritus, of Economics

CHANCELLORS

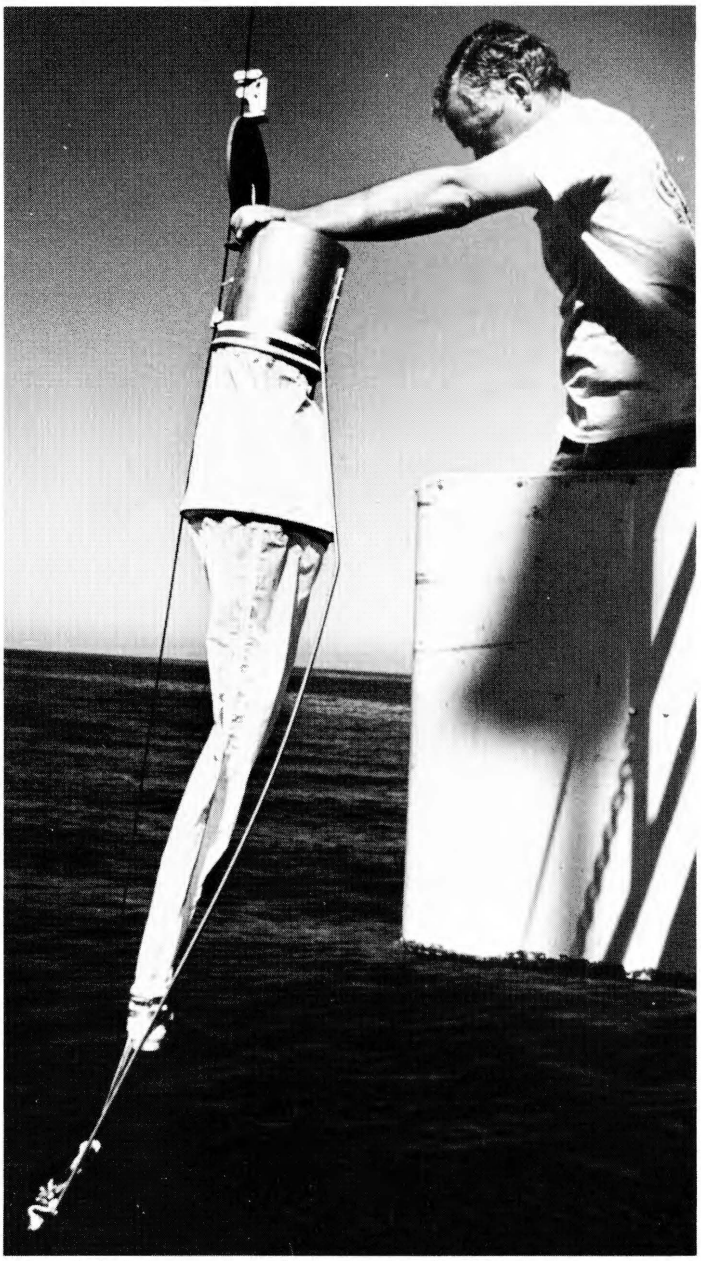
Albert H. Bowker
Chancellor at Berkeley
James H. Meyer
Chancellor at Davis
Daniel G. Aldrich, Jr.
Chancellor at Irvine
Charles E. Young
Chancellor at Los Angeles
Ivan Hinderaker
Chancellor at Riverside
William D. McElroy
Chancellor at San Diego
Francis A. Sooy
Chancellor at San Francisco
Robert A. Huttenback
Chancellor at Santa Barbara
Robert L. Sinsheimer
Chancellor at Santa Cruz

Appendix G

CURRENT FUNDS EXPENDITURES 1976-1977

	Institutes			
	Scripps Institution of Oceanography	Geophysics and Planetary Physics	Marine Resources	Total
STATE GOVERNMENT	$ 4,574,051	$ 195,820	$ 735,605	$ 5,505,476
FEDERAL GOVERNMENT				
Department of Defense				
Air Force	371,979	78,860	—	450,839
Army	—	—	2,862	2,862
Navy	4,870,506	389,177	63,051	5,322,734
National Institutes of Health	224,918	—	4,572	229,490
National Aeronautics and Space Administration	52,843	103,812	—	156,655
Department of Health, Education, and Welfare	27,251	—	1,852	29,103
National Science Foundation	23,189,361	482,796	420,270	24,092,427
Energy Research and Development Administration	232,661	81,933	405,040	719,634
Other	896,774	11,685	853,751	1,762,210
Total Federal Government	29,866,293	1,148,263	1,751,398	32,765,954
LOCAL GOVERNMENT	1,472	—	—	1,472
PRIVATE GIFTS, GRANTS, AND CONTRACTS	1,594,901	128,550	46,036	1,769,487
ENDOWMENT FUNDS	321,588	28,257	168,693	518,538
OTHER SOURCES	(202,893)	(16,158)	7,342	(211,709)
Total Current Funds Expenditures	$36,155,412	$1,484,732	$2,709,074	$40,349,218

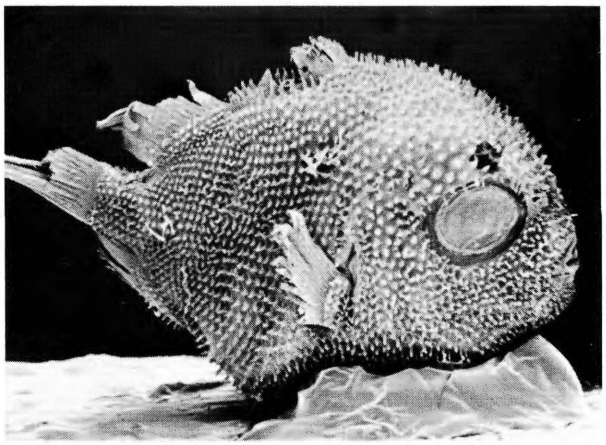
NOTES



From the hydrobucket of R/V Alexander Agassiz, *Gene L. Stewart lowers a phytoplankton net down the hydrowire during operations off San Diego on Farewell to Aggie, the ship's last cruise before retirement from the fleet.*

David A. Goldstein,
San Diego State University

NOTES



Scanning-electron micrograph of 3-mm juvenile rough triggerfish, Canthidermis maculatus, *from the marine vertebrate collection. The animal was taken in a neuston net in the surface waters of the Gulf of California. Adults of this species can grow to 22.4 cm in length.*

Ellen L. Flentye

University of California, San Diego
Q-036
La Jolla, CA 92093

Second Class
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