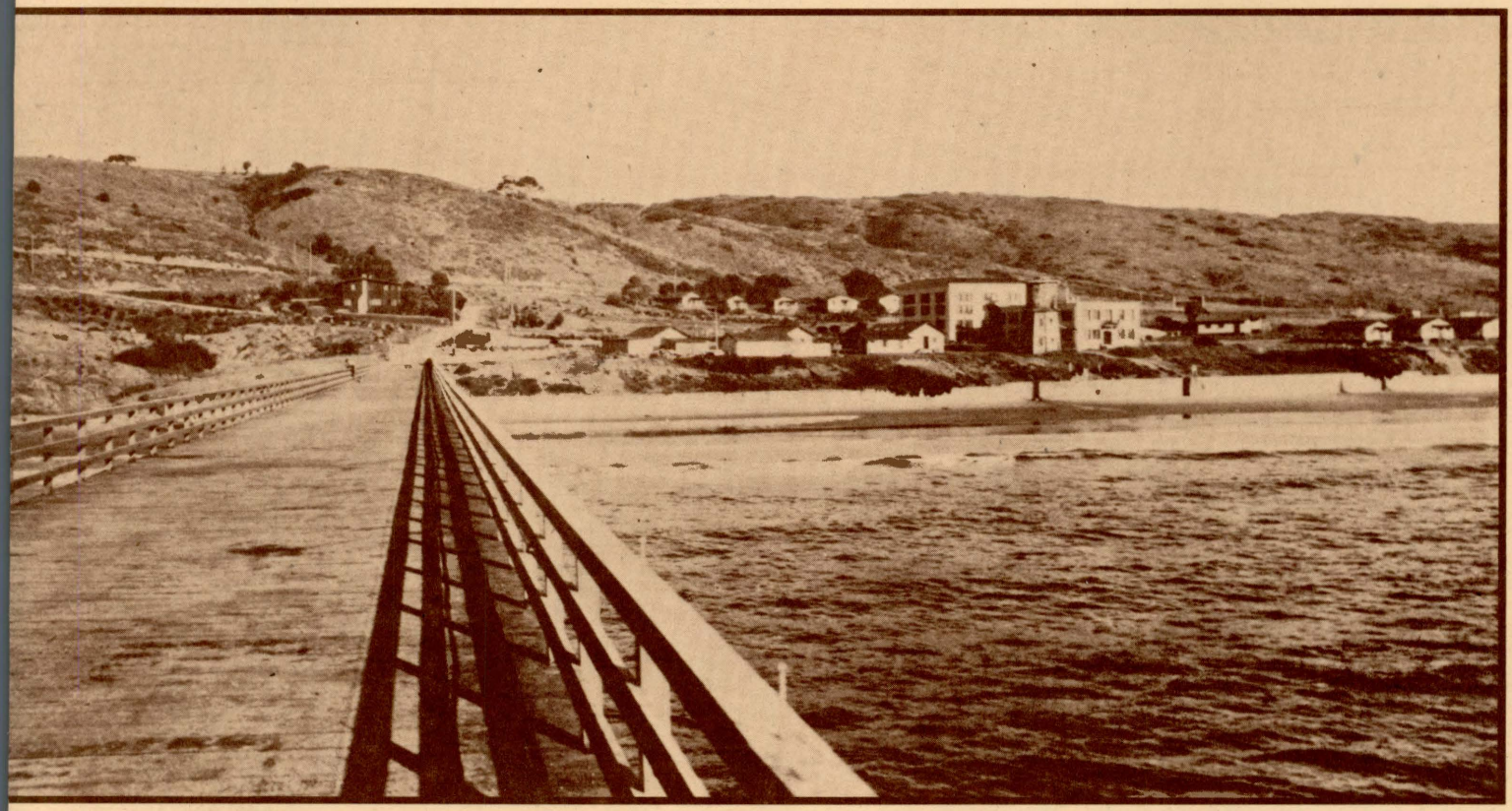
Scripps Institution of Oceanography 1978

University of California, San Diego



UCSD

Published by the University of California, San Diego
Public Information Office, Building 211, Q-036

Volume 12, Number 1: January 1979

A series of administrative publications of the University of California, San Diego, La Jolla, California 92093. Second-class postage paid at La Jolla, California

Four issues a year: January, March, May, and July

All announcements herein are subject to revision. Changes in the list of Officers and Administration may be made subsequent to date of publication.

A major fraction of the work reported herein was supported by the Office of Naval Research and the National Science Foundation.

Unless credited otherwise, photographs have been provided by the Office of Learning Resources' photographic laboratory of Scripps Institution of Oceanography.

Gover photo: Scripps Institution of Oceanography, August 1927.

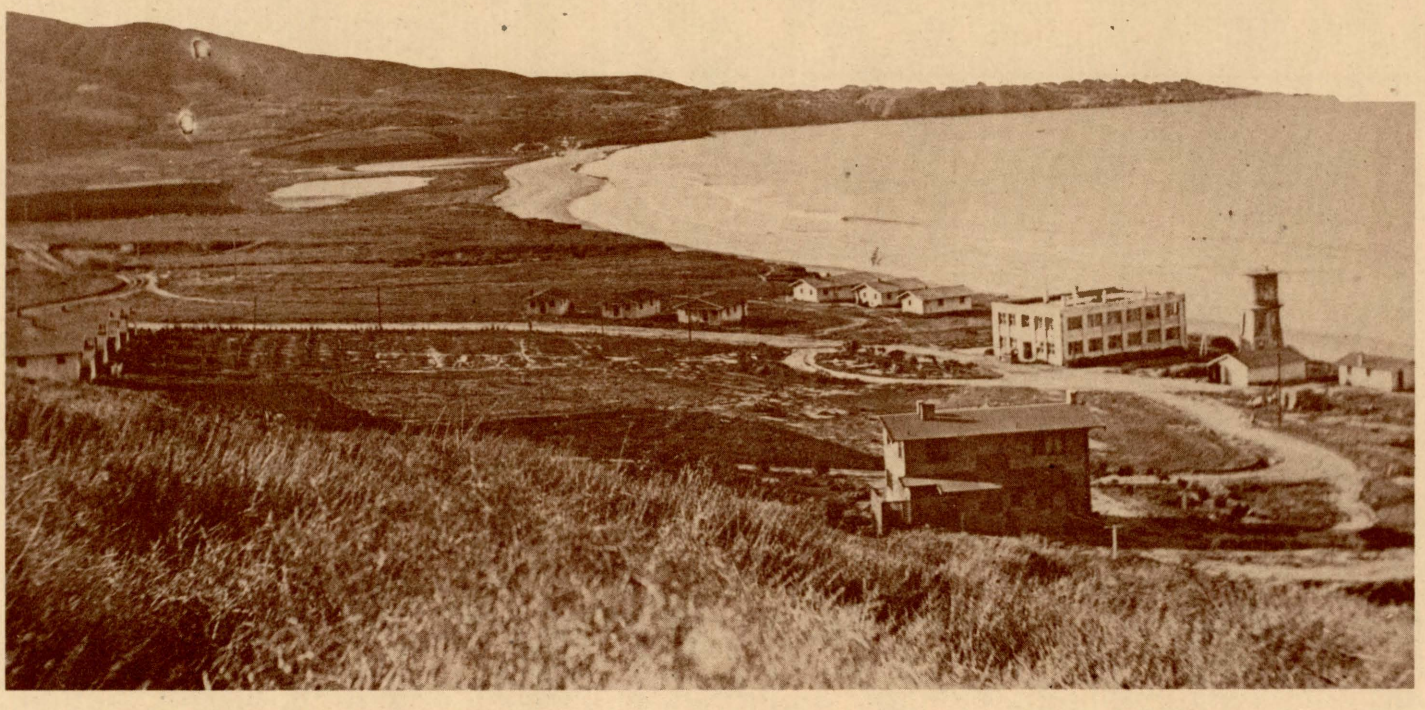
Scripps Institution of Oceanography, 1914

SCRIPPS INSTITUTION OF OCEANOGRAPHY

UNIVERSITY OF CALIFORNIA, SAN DIEGO

1978

75th Anniversary Edition

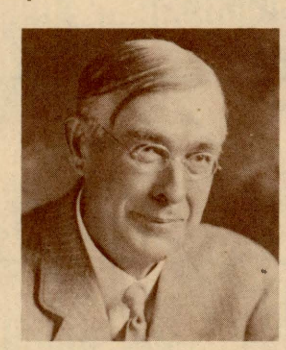


DEDICATION

We salute the founders of Scripps Institution of Oceanography. Their backgrounds, their origins, their professions were very different, but they united in a common goal in 1903. Three-quarters of a century later, Scripps Institution of Oceanography again acknowledges its principal founders:

WILLIAM EMERSON RITTER

We honor the vision and breadth of William E. Ritter, farm boy turned professor, who, while chairman of the Department of Zoology at UC Berkeley, sought a location for a summer study program. As resources became available, he enlarged his modest project into a nationally recognized institution. Expert on tunicates, widely recognized among his peers as a philosophical biologist, Ritter was an all-round naturalist whose "broad vision and penetrating insight . . . enabled him to direct the studies of his associates at the Institution into productive channels."

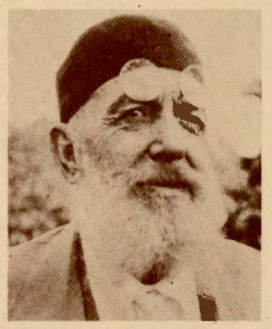


FRED BAKER

We honor the enthusiasm of Fred Baker, a San Diego physician with "an insatiable interest in natural sciences." He sought out Ritter when he heard of a possible summer science program, with the appeal: "For such work as you are planning, I feel sure San Diego offers the greatest chances of any point on the coast." Baker selected the San Diego community leaders who could finance a major undertaking. One of them, Homer H. Peters, introduced him to E. W. Scripps. A leader in all the scientific organizations in San Diego, and an often-elected member of civic boards, Baker was also an avid shell collector who published on molluscs and served as honorary curator of molluscs at this institution for some years.

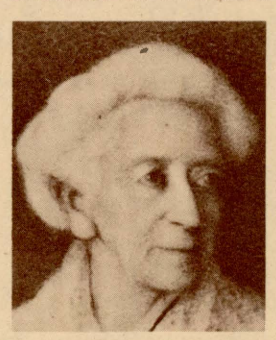
EDWARD WILLIS SCRIPPS

We honor the astuteness of Edward Willis Scripps, who acknowledged Ritter's eminence in a field unknown to himself and supported the scientist generously. The self-styled "damned old crank," almost a recluse, champion of the working man in the thirty newspapers that he controlled, E. W. Scripps was fascinated by what he called "the human animal." In addition to setting this institution firmly on its feet, he and Ritter established Science Service to carry to the people authentic news of scientific developments.



ELLEN BROWNING SCRIPPS

We honor the generosity of Ellen Browning Scripps, who was reared on hard work and self-sufficiency to attain a fortune that she gave to others. Schoolteacher, proofreader, early syndicated columnist ("Miss Ellen's Miscellany") in her brothers' newspapers, dedicated suffragette, and a warm human person was Miss Scripps. All members of her family depended upon her in times of illness or crisis, and they sought her business advice constantly, especially her younger half-brother Edward. Miss Scripps's gifts to La Jollá began as soon as she built her first house in the little village in 1897. Ritter's vision appealed to her, and from the founding, in 1903, of the association that became this institution she contributed funds for all of its needs in buildings and programs.



HISTORICAL COLLECTION, TITLE INSURANCE AND TRUST COMPANY, SAN DIEGO, CALIFORNIA

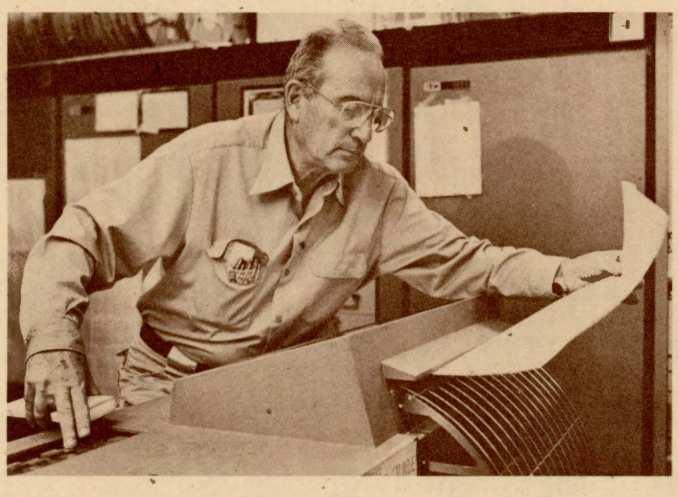
The first base of operations for the San Diego Marine Biological Institutton, forerunner of Scripps Institution of Oceanography.

TABLE OF CONTENTS

Dedication 1
Introduction 3
Research Activities 5
- Geological Research Division 5
- Marine Biology Research Division 9
- Ocean Research Division 12
- Marine Physical Laboratory 17
- Physiological Research Laboratory 19
- Visibility Laboratory 21
- Deep Sea Drilling Project 22
- Marine Life Research Group 24
- Neurobiology Unit 26
- Institute of Geophysics and Planetary Physics 27
- Institute of Marine Resources 29

Seagoing Operations 35
Graduate Department 38
Shore Facilities and Collections 40
Publications 45
Staff 55
Appendix A: Organization Chart 61
Appendix B: Sponsors of Research and Graduate Instruction 62
Appendix C: Awards and Honors 63
Appendix D: Specifications of Research Vessels 63
Appendix E: Doctor of Philosophy Degrees Awarded in 1977-78 with Titles of Dissertations 64
Appendix F: University Officers and Regents 65
Appendix G: Current Funds Expenditures 1977-78 66

INTRODUCTION



I write this in the midst of the celebration of the 75th year of the Scripps Institution of Oceanography. It is clear from the tempo of this year's activities that the institution will be around for a long time to come.

Actual money spent by the institution increased by 13 percent over the previous year and is just nudging $50,000,000. Two new buildings were dedicated this year — the Carl Eckart Building of the Scripps Institution of Oceanography Library, and the Marine Biology Building — and we are already pressed for space again.

In previous years, we've noted the importance in today's world of climate, the carbon dioxide problem, and the advent of the new technologies such as space vehicles. Dr. Keeling and carbon dioxide have become household words. The public consciousness of these problems and opportunities has risen to the point where the demands on the institution are really exceeding our capacity.

In addition to the new buildings, this year has been the construction year for R/V *New Horizon*, which will be delivered soon. On top of the planning, orderly acquisition of the new buildings and the new ship, we will have to adjust ourselves to the installation and use of a 5-m antenna dish and ancillary equipment for satellite oceanography. In parallel, a very close liaison is developing with the Jet Propulsion Laboratory in the application of space technology to short-range climate prediction and physical oceanography.

As a result of initiatives undertaken by the Governor of the State of California, the university has established a statewide institute that will be called Cal Space. This institute will be housed at Scripps partly as a reflection of the extensive remote-sensing activity at the institution.

We are also in the process of establishing a center for climate prediction research at the institution. This is being done in cooperation with the federal government. It is an obvious development from the NORPAX program activities.

In certain areas we do expect similar developments. One of them is involvement in the field of energy from the oceans. Another is related to the accelerated interest by the United States Navy in physical oceanography in the thermocline and the mixed layers.

It is not clear how we will be able to physically handle all of these developments — but at least life will not be dull!

These last years have brought the renewal of our ties to Mainland China. We are now developing relationships with additional countries in the Middle East; specifically, Saudi Arabia, Syria, Jordan, and Turkey. We continue to enjoy good relations with Egypt and Israel.

It's tempting to make wild guesses where all of this will lead. During the 75th anniversary time, some of us of a certain age tried to look ahead twenty-five years. The one extraordinary effect is that for a long time Scripps's spending has doubled each six to seven years, which means that the institution's spending will be close to $300,000,000 by the year 2003.

William A. Nierenberg

William A. Nierenberg, Director
Scripps Institution of Oceanography

SCRIPPS INSTITUTION OF OCEANOGRAPHY 1978

RESEARCH ACTIVITIES

The Research Activities section gives only a brief overview of the various scientific projects being carried on at Scripps Institution of Oceanography. Support for these projects has come for the most part from the National Science Foundation, Office of Naval Research, National Oceanic and Atmospheric Administration, and National Institutes of Health.

The scientific articles listed in the Publications section will lead the reader to a more in-depth coverage of the topics discussed below.

Geological Research Division

Volatility of rocks, evolution of the earth's crust, formation of ferromanganese nodules, and exploration of the Indian Ocean are just a few of the many studies carried out by the Geological Research Division.

Scientists in the laboratory of Dr. Edward D. Goldberg have been involved in such diverse projects as the volatility of rocks, the biogeochemistry of uranium, the fallout history of nuclear weapons debris in glaciers, and the age determination of bivalves by chemical means.

Dr. Goldberg and Dr. Georges Desaedeleer, Université de Louvain, Belgium, determined elements volatilizing from a basalt and from a rhyolite at room temperatures by making the rocks radioactive through exposure in a slow neutron pile and then by identifying the radioactive species that distilled off the rocks. Selenium, antimony, zinc, and mercury were among the more volatile elements, and the results suggest that there may be substantial contributions of these metals from rock volatility to the atmosphere. Further, there was nearly a complete covariance in the enrichments of metals noted in the distillates from the rocks and in the metal burdens of the atmosphere in the north and south polar regions. These initial experiments will be extended through direct measurements of the fluxes of metals from rocks with a laser fluorescence spectrometer now being constructed.

The uranium isotopes in dissolved and particulate states in seawater have different isotopic compositions. As a consequence, the role of these particles and of the soluble forms of uranium can be assessed in the accumulation of this element by plants and animals in the coastal marine environment; this was demonstrated in work carried out by Dr. Vernon F. Hodge. Mussels, for example, gained most of their uranium from the dissolved state in seawater, while some tunicates accumulated their uranium primarily from the solid phases derived from rock weathering. Algae, such as the attached kelps, preferentially took up the dissolved forms.

The fluxes of transuranic elements and fission products from nuclear bomb debris to the earth's surface have been measured in the various strata of the Ross ice sheet (80° 22′S and 168° 40′W). The glacial records are the most sensitive and accurate fallout histories for these nuclides that are obtainable today. Most of these radioactive substances have spent some time in the stratosphere before returning to the earth's surface. Coupling these data with those obtained previously for the arctic ice sheets may provide the meteorologist with data to study interhemispheric mixing processes in the troposphere and stratosphere.

The ages of mussels collected from natural habitats may be determined by the amounts of heavy metals in their soft tissues or in their shells. Some heavy metals have long retentions by these organisms (for lead, it appears a matter of years). These chemical techniques of age determination have a much greater sensitivity and accuracy than do those methods based upon physical dimensions, such as shell length, or upon seasonal bandings in the shells.

A variety of problems in nuclear geochemistry and geochemistry have been recently investigated by Dr. J. Douglas Macdougall and his colleagues. In order to learn more about the upper-mantle source regions of oceanic basalts, and the evolution of the earth's crust in general, they examined the isotopic composition of neodymium (a rare-earth element) in a selected suite of oceanic rocks. This project with Dr. Gunter W. Lugmair, UC San Diego, and graduate student Richard W. Carlson revealed new information about the chemical heterogeneity of the upper mantle and the time scale of chemical fractionation in the mantle. The radioactive decay of ^{147}Sm to ^{143}Nd causes the neodymium isotopic composition in any system to change with time, thus allowing its use as a tracer for rock source regions.

Use of alpha-radioactivity "maps" to measure the accumulation rates of manganese nodules continued as part of the National Science Foundation's International Decade of Ocean Exploration (NSF-IDOE) Manganese Nodule Project. The aim of this research is to document the rates at which various transition metals are incorporated into nodules. For this work a consortium of investigators from several institutions has been set up, each of whom brings specialized techniques to bear on a common sample. In addition, the high-resolution alpha-track "maps" are being used to examine the processes by which radionuclides are taken up by nodules, and how they behave after incorporation.

The contents and isotopic composition of uranium in oceanic basalts and their alteration products have been measured. This research, carried out with Dr. Robert C. Finkel, demonstrated that although uranium uptake is characteristic of seawater alteration of basalts, different alteration phases behave quite differently with respect to this process. Analysis of Deep Sea Drilling Project old basalts with thick sediment cover indicated that little communication with "fresh" seawater uranium occurs.

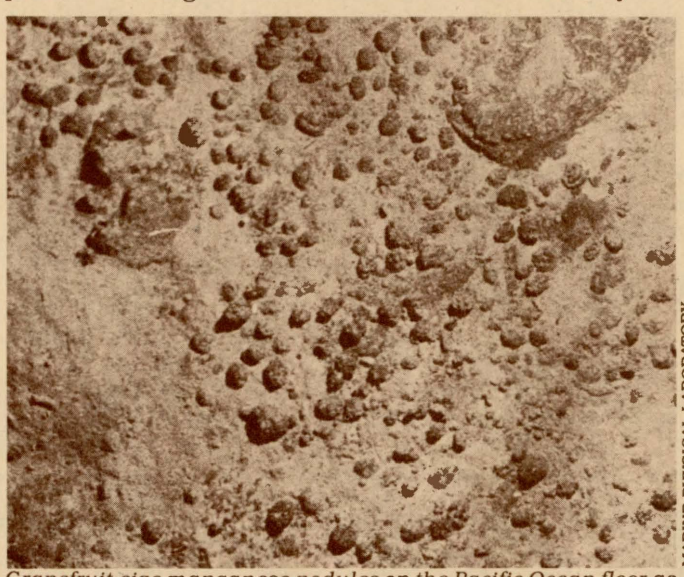
Graduate student Sally Newman has begun analyses of the uranium distribution and concentration in the upper mantle by studying a suite of ultramafic nodules from a worldwide set of volcanic rocks and kimberlites.

Studies of carbonaceous chondrites, meteorites that may hold clues to the composition of the earth, have continued; the most exciting aspect was the discovery of very large isotopic "anomalies" in the C2 chondrite Murchison. In this meteorite, small inclusions were found that have very refractory chemical compositions and contain relatively large amounts of the rare mineral hibonite, a calcium-aluminum oxide. The possibility that this mineral represented an early solar system condensate led to studies of its isotopic composition, particularly for the element mag-

nesium. The extremely small grain size of hibonite precluded conventional mass spectrometric analyses, and measurements were undertaken on the ion microprobe at the Johnson Space Center, Houston, Texas. These analyses identified extremely large (by terrestrial standards) mass fractionation effects for magnesium isotopes in some of the Murchison material. Although the origin of these anomalies is not yet understood, they must reflect a very early solar system process.

Dr. Gustaf Arrhenius' group continued their work on experimental and theoretical modeling of the chemical isotope fractionation effects, which are observed in the interstellar medium, in meteorites, and in the particulate matter in the Junge layer of the upper atmosphere. The initial investigations of the fractionation of nitrogen (up to 42 percent of terrestrial nitrogen) in reactions with oxygen have been completed. Present work concerns the nonlinear fractionation of oxygen isotopes, which is particularly noticeable in what is believed to be primordial condensates in carbonaceous meteorites.

The other major effort in the group concerns the crystal chemistry of manganese hydroxy-oxide sheet structure minerals forming on the deep ocean floor as a major component of manganese nodules. The aim is to clarify the



MARINE PHYSICAL LABORATORY

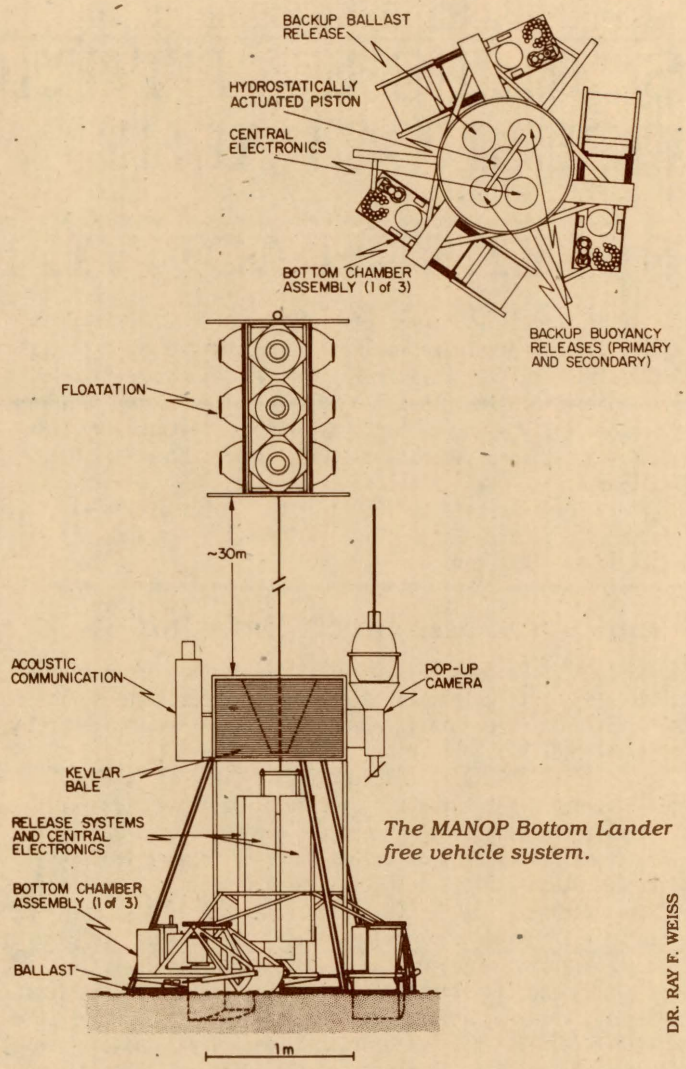
Grapefruit-size manganese nodules on the Pacific Ocean floor as photographed by the Marine Physical Laboratory's Deep Tow.

mode of substitution in these structures with ions, particularly of copper, nickel, cobalt, and cerium. For this purpose the minerals are being synthesized under controlled conditions, and the substitution equilibrium and kinetics measured. The details of ionic position and coordination in the lattices both of the synthetic and the naturally occurring minerals are being studied with new high-resolution techniques. Among these is X-ray absorption fine-structure analysis, made possible by the powerful beam of polarized synchrotron X rays from the storage ring at the Stanford Linear Accelerator, Stanford, California.

Other input into these investigations comes from the systematic chemical analysis of the minerals as they occur naturally in the manganese nodules, and from statistical analysis of the large number of data now accumulated in the Scripps Sediment Data Bank.

The chemical, petrological, and bathymetric aspects of technological potential of the siliceous radiolarite sediment in which the highly copper-nickel substituted manganese nodule deposits occur was investigated.

The *in situ* study of chemical and biological processes occurring at the sediment-water interface and their rela-



The MANOP Bottom Lander free vehicle system.

DR. RAY F. WEISS

tionship to the formation of ferromanganese nodules is the subject of new research being carried out under the direction of Dr. Ray F. Weiss. As part of the Manganese Nodule Program (MANOP) sponsored by NSF's IDOE, Dr. Weiss's group has undertaken the design, fabrication, and deployment of the MANOP Bottom Lander free-vehicle system. This device will operate in water depths up to 6 km and will be deployed for periods up to one year. During the experiment, a time-series of water samples will be taken from each of three separate chambers placed over the sediment and nodules. Each chamber may be spiked with various chemical and isotopic tracers, and dissolved oxygen and pH will be measured *in situ*. At the completion of the experiments, a box core will be taken under each of the chambers, and the entire vehicle will return to the surface with the water and core samples.

Dr. Weiss also continued his work on water-column chemistry and on dissolved gases. While aboard R/V *Melville* during the antarctic leg of the GEOSECS Indian Ocean Expedition, Dr. Weiss traced the hydrography and geochemistry of the deep water masses on either side of the Kerguélen Plateau. On this cruise, and on the three preceding cruises of Indomed Expedition, Dr. Weiss's group carried out continuous underway measurements of nitrous oxide in the atmosphere and in surface water. This important trace gas acts as the major natural modulator of the earth's ozone layer and thus controls the penetration of solar ultraviolet radiation to the earth's surface. The results of these measurements show that the oceans represent a net source of nitrous oxide, but that the magnitude

of this source is far less than had been previously proposed. Instead, nitrous oxide appears to be an extremely valuable tracer of local upwelling and vertical mixing phenomena.

Dr. Devendra Lal's group at Ahmedabad, India, devoted much of their work to the GEOSECS Indian Ocean Expedition this year aboard R/V *Melville.*

Dr. Robert L. Fisher continued his investigations of the evolution and structure of the Indian Ocean and of plate movements since mid-Mesozoic time, in collaboration with scientists from the Massachusetts Institute of Technology (MIT). In shipborne field work, Dr. Fisher directed a four-week tectonic examination of the seismically active and deeply segmented Southwest Indian Ridge far south of Madagascar. Scientists aboard *Melville* used bathymetric, magnetic, and seismic-reflection and profiling to discover and delineate huge lipped meridional cross-fractures cleaving the ridge that were sampled by dredging. Anorthositic plutonics and relatively silicic gneisses and other metamorphics comprised an unusually large fraction of the rocks recovered far from any islands; major components were assorted gabbroic species and partially serpentinized mafics and ultramafics. In a two-ship seismic refraction/sonobuoy program with the French R/V *Marion Dufresne*, Cambridge University, England, and Institut de Physique du Globe de Paris, France, scientists worked with the Scripps-MIT team to make two long profiles on Madagascar Ridge, and established the essentially noncontinental structure of that very extensive, shoal, leveled, and faulted feature. Dr. Fisher continued participation in the field work of the International Geological Correlation Program's "Project Ophiolites," this year in North America's Stillwater Complex, Montana, and Klamath Mountains, California and Oregon.

Dr. Joseph R. Curray has devoted his time to two principal projects: a continuation of his study of the tectonics and geological history of the northeast Indian Ocean, and serving as chairman of the IPOD (International Program of Ocean Drilling) Passive Continental Margin Advisory Panel.

After leading and participating in three legs on Indopac Expedition in the Andaman Sea and southwest of Sumatra during the last year, Dr. Curray and his colleagues have engaged in analysis and interpretation of data from that and previous expeditions. He and graduate student Robert M. Kieckhefer and U Hla Tin and U Aung Min, of the Myanma Oil Corporation, Rangoon, Burma, collaborated in reducing and interpreting three, long, seismic-refraction lines taken in cooperation with the Burmese in the Andaman Sea. They also worked with Dr. Lawrence A. Lawver on heat flow and magnetics.

Data collected from the central Sunda Arc transect, running from central Sumatra southwestward through Nias Island and across the Sunda Trench, are also being analyzed and reduced. The workshop on preliminary results of this transect study was held in Prapat, Sumatra, Indonesia. Following this workshop, Dr. Curray visited Medan, Sumatra; Kuala Lumpur, Malaysia; and Rangoon, Sandoway, and Mandalay, Burma, to discuss results of the cooperative study and to visit important geological localities.

The Isotope Laboratory research group, Drs. Harmon Craig, Yu-chia Chung, and John E. Lupton, was primarily concerned with the GEOSECS expedition in the Indian Ocean on R/V *Melville.* They carried out studies of dissolved and particulate lead-210 and measured radon profiles in the bottom water.

After the expedition Dr. Craig and Valerie Craig did field work in Madagascar, continued their African Rift valley studies in northern Kenya, and then went to Israel to participate in a joint "oceanographic" study of the Dead Sea with the Weizmann Institute and to study geothermal features in the Jordan Rift. Dr. Chung collected samples in the geothermal area of northern Taiwan, while Dr. Lupton worked in New Zealand collecting samples in the major geothermal areas of North Island.

The major emphasis in the geothermal studies during the past year has been the comparison of helium isotope ratios in proposed "hot spot" or "mantle plume" areas with ratios in other volcanic areas (on land and in "hydrothermal plumes" in ocean spreading centers). Three suspected hot spot areas, Kilauea Volcano, Hawaii; Yellowstone National Park, Wyoming; and the Ethiopian Rift valley, were found to have He^3/He^4 ratios about 15 times the atmospheric ratio, while all other areas studied (Hakone Volcano, Japan; Lassen Peak, California, and others) have ratios similar to that in basaltic glasses — about ten times atmospheric or less. Recent Russian work has shown that Icelandic geothermal gases also have the "Kilauea type" helium; thus it appears that the so-called hot spots can be clearly identified by the helium isotope ratio.

Dr. Chung hurried home to receive an air shipment of Dead Sea samples for excess-radon measurement (half-life four days), an arrangement made at great effort to minimize travel time. Unfortunately, it was found that there is no excess radon in the Dead Sea! However, very high radium concentrations, some 300 times greater than in Pacific Deep Water, were discovered, together with extremely high methane concentrations in the deep water. Dr. Lupton also found a large helium excess in the Dead Sea deep waters; the helium isotope ratios showed this to be crustal (radiogenic) helium, very similar to the helium previously found as an injected component in Lake Tanganyika deep water in Africa.

Valerie Craig continued work on isotopic studies of Greek marbles from sculptures and quarries. Marble from the famous Nereid Monument of Xanthus was found not to be Parian marble as had previously been thought. A clear grouping of sculpture marbles from Xanthus and Miletos, Turkey, and Halicarnassos, Sounion, Bassae, and Epidauros, Greece, unassociated with any quarry so far investigated, emerged from this work. Further field work in southern Greece and Asia Minor is planned in order to examine other ancient quarries. She also found that the marble pillars discovered in the sea off Bimini in the Bahamas are not similar isotopically to any classical quarries of Greece, as had been proposed by pro-Atlanteans; in fact, they resembled most closely the marbles cut out of the Simplon Tunnel in the Swiss Alps.

Other work in the division included a continuing investigation of Mesozoic deep-sea sediments by Dr. Hans R. Thierstein that showed the entire deep Atlantic Ocean became oxygen deficient in the middle Cretaceous, whereas in the Pacific, strong anaerobism was limited to a relatively shallow oxygen minimum zone. This, in conjunction with newly discovered changes in carbonate accumulation patterns, suggests a pronounced deep-water fractionation between the major Late Cretaceous ocean basins.

The ocean-bottom seismograph group has participated in four expeditions this year. The first of these was an extension of a long seismic-refraction profile east of Hawaii to a range of 1,000 km; information about the oceanic lithosphere structure was obtained to a depth of approximately 100 km. The second expedition was to the Galápagos Rise to investigate the elastic properties underlying a slow spreading center. This trip completes a four-year study of spreading center structure using explosion methods. Field work was conducted on Lopez Island in Puget Sound off Washington, in an effort to compare and calibrate ocean-bottom seismographs from across the United States. Scientists on the final expedition, to Iceland, conducted a detailed array study using explosives around a continuously cored, 2-km-deep hole in the Ice-

land basement. The goal is to compare the results of advanced seismic analysis methods with the physical properties of deep crustal rock.

Drs. Robert D. Moore and LeRoy M. Dorman and graduate student Chin-Yen Huang have almost completed the development and construction of several new ocean-bottom seismographs, which include microprocessor control, digital recording, and broad-band sensor response. These instruments will be used for the first time in the upcoming Rivera Ocean Seismic Experiment, which will employ both explosions and earthquakes as sources.

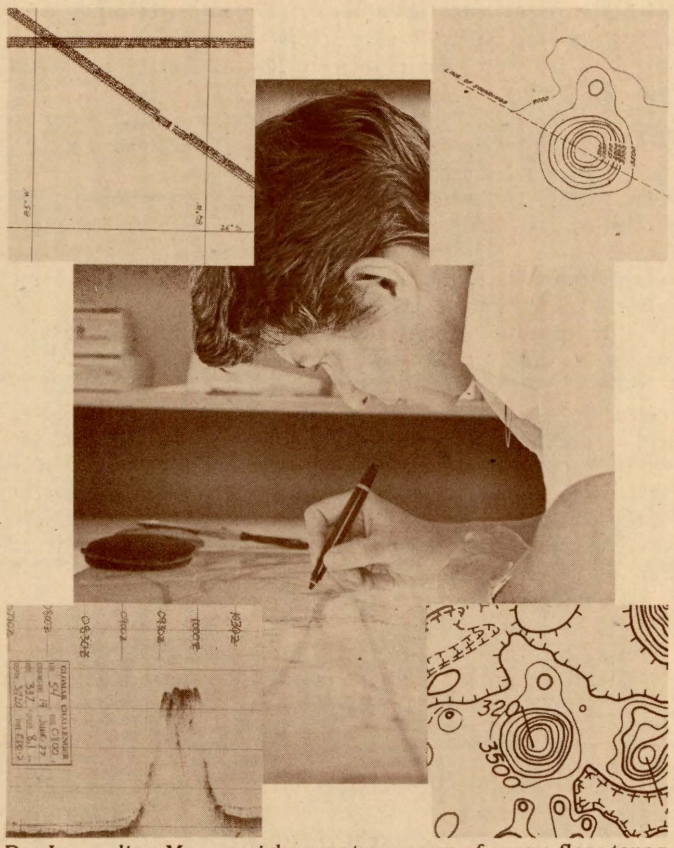
Dr. John A. Orcutt and graduate student Jan D. Garmany have implemented the asymptotic propagator theory of Woodhouse in calculating synthetic seismograms of body waves and have developed a linear inverse theory for travel-time analysis. Graduate student Paul A. Spudich, Dr. Matthew H. Salisbury, and Dr. Orcutt have completed a study of compressional and shear wave propagation in the oceanic crust and have related the results to physical property measurements from the Bay of Islands, New Foundland, ophiolite suite. Dr. Orcutt has conducted a study of compressional wave propagation in the upper mantle under the western United States with Dr. Larry Burdick, California Institute of Technology, Pasadena. Dr. Orcutt is also studying the propagation of seismic body and interface waves on the sea floor in collaboration with scientists from UC San Diego.

Dr. Thomas H. Jordan continued his work on the deep structures of the continents. He has found that beneath the old continental nuclei, there exist root zones several hundred kilometers in thickness that translate coherently with the continents during plate motions. These zones are apparently stabilized against convective disruption by the depletion of the continental upper mantle in a basalt-like component. In Dr. Jordan's model these thick depleted root zones are constructed by the dynamic and magmatic processes associated with continental drift and convective cycling of the sea floor. This model and other hypotheses concerning mantle dynamics are being tested with seismic data. Through the use of recently developed theoretical techniques and digitally recorded seismic data from global networks, graduate students Stuart A. Sipkin and Paul G. Silver are working with Dr. Jordan to construct realistic three-dimensional models of large-scale structure in the earth's upper mantle.

On a considerably smaller geographic scale, graduate student Keith A. Sverdrup and Drs. Kenneth C. Macdonald and Jordan have been investigating the seismicity and structure of the Middle America Trench. The data were collected in 1977 by an array of ocean-bottom seismometers and a land-based seismic network at a site near Acapulco, Mexico, during a joint experiment with seismologists from the Mexican National University, Mexico City. In the study area, they found the accretionary prism of sediments being piled up against the continent by the subduction process is nearly aseismic except along a well-defined fault zone perpendicular to the trench axis. This fault zone appears to extend for a considerable distance from the trench northeastward into the metamorphic basement complex of the Mexican coast range.

During the year, Dr. Jacqueline Mammerickx has completed a reevaluation of the ocean floor morphology of the Nazca Plate. A new model of the tectonic evolution of the Southeast Pacific has been developed that resolves previously contradictory observations made on the Nazca Plate.

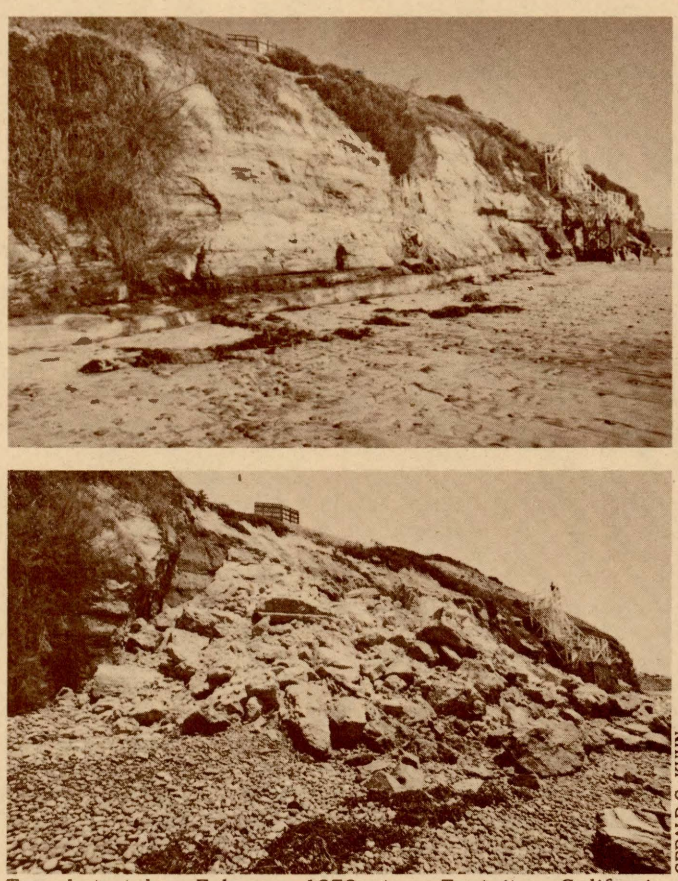
Highlights of the past year for Drs. Wolfgang H. Berger, Edith Vincent, and John S. Killingley included the discovery of disequilibrium precipitation of calcareous skeletal material by planktonic and benthic foraminifera and by deep-sea fishes (rattail). The degree of disequilibrium — especially of the $\delta^{13}C$ composition — appears to be a measure of the intensity of metabolic activity. The carbon isotope signal was found to be useful in the study of the history of upwelling off Northwest Africa. Also, the work on the deglacial meltwater spike continues, with a scrutiny of the mixing processes on the sea floor that changes both the signal recorded and its apparent age, based on ^{14}C stratigraphy.



Dr. Jacqueline Mammerickx creates a map of ocean floor topography, center, from data collected on Scripps research vessels. Depth recorders operate continuously and generate a sound signal that is reverberated on the sea floor, inset lower left. Soundings are read every six minutes, translated into fathoms, digitized, and fed, with their coordinates, into a computer that can plot all known soundings in a given area, upper left. Contours are drawn using these data; in this case the single crossing of a large flat-topped seamount is interpreted as a simple conical feature, upper right, and included in the general topography of the area, lower right.

This group continued to work on refining isotopic and sedimentologic methods of paleo-environment analysis in Quaternary oceans, laying the groundwork for studying Miocene-Pliocene oceans, tying acoustic stratigraphy to changes in sedimentation patterns, and trapping the sediment particles produced in the productive upper layer, as they fall to the sea floor.

Dr. William R. Riedel and co-workers are exploring the application of computer-age technology to planktonic microfossils. They are cooperating on the computer storage of radiolarian descriptors and sketches as an alternative to Linnean names and on 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. It has recently been determined, on the basis of these microfossils, that a column of clay sediment from the north-central Pacific has accumulated at the very low rate of 0.3 m per million years for the past 70 million years. Dr. Riedel's group continued conventional stratigraphic and taxonomic work on radiolarians from the European Mesozoic and Deep Sea Drilling Project Cenozoic sequences.



GERALD G. KUHN

Top photo taken February 1978 at an Encinitas, California, beach. Bottom photo of same area from same position taken April 1978 shows results of winter storms; a section of the bluff 35 m long and 12 m high collapsed.

Dr. Francis P. Shepard has recently finished writing the most comprehensive study ever made of bottom currents that included more than 25,000 hours of continuous records from various parts of the world. The four records of turbidity currents reported are virtually the only ones ever recorded by current meter.

The work on bluff erosion in the area north of San Diego, conducted largely by Gerald G. Kuhn, has shown considerable progress during the year, and many of the predictions from previous work have been verified as the result of the heavy rains and storm conditions that hit the southern California coast during the past winter.

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.

Dr. Walter J. Desmond is continuing the investigation of the possible role of silicon in certain diseases; such as, asbestosis and lung carcinomas. Previously it was demonstrated in this laboratory that exposing lung cells in tissue culture to silicate produces drastic changes in cell viability, metabolism, morphology, and the possibly tumorigenicity. Recent work has shown that the silicate-induced inhibition of overall growth is not caused by direct inhibition of DNA synthesis, nor by an increase in cell death, thus indicating that some other processes must be inhibited.

Continued study of the dramatic change in the ultrastructure of the cell upon exposure to silicate suggests that initial action at the membrane leads to changes in the cytoskeletal structure. In order to elucidate some of the factors (silicate polymer/monomer ratio) that influence silicate inhibition, silicate binding was investigated with radioactive (^{31}Si) silicic acids. Polymeric silicate binds to the cell, while the monomeric form continues to combine with the bound polymer and stabilizes it. It now appears that it is the polymeric silicate that predominantly affects cell growth.

Dr. Desmond, in collaboration with Dr. Linda L. Nardone, Yale University Medical School, New Haven, Connecticut, has extended the work with animal cell models to differentiated, functional, human lung carcinoma cells in order to investigate the silicate effects on their growth, metabolism, and ultrastructure.

Silicon appears to play a role in regulating gene activity in the diatom. The levels at which regulation may occur are being studied by Christopher Reeves, a UC San Diego graduate student, to determine the effects of silicon in *Cylindrotheca fusiformis* on initiation and elongation of protein synthesis and the complement of messenger RNAs undergoing translation.

Dr. Francis T. Haxo and associates have continued their studies of algal pigments and their role in photosynthesis and distribution in various algal groups. An interesting finding by Dr. Haxo is that zooxanthellae isolated from a specific soft coral have an unusual pigment composition not characteristic of symbiotic dinoflagellates. The presence in the symbiont of fucoxanthin, and chlorophylls c_1 and c_2 suggests that the alga is probably a chrysophyte.

Drs. Phillip Dustan and Haxo are examining light adaptation in the symbiotic dinoflagellate algae (zooxanthellae) of reef-building corals. Dr. Dustan recently completed a study of the photophysiology of freshly isolated algae and a detailed characterization of the reef's photic environment at the Discovery Bay Marine Laboratory, Jamaica.

Dr. Arthur Ley received his Ph.D. this year after completing his dissertation that elucidated the pathways of energy capture and flow through the light harvesting photosynthesis apparatus of the red alga *Porphyridium cruentum*.

Dr. Haxo's group continues to maintain a large culture collection of marine microalgae with emphasis on dinoflagellates. Major internal use of this collection has been for studies in photosynthesis and the nature and distribution of many natural products.

Dr. Ralph A. Lewin's work continues on various green algal symbionts, and on the autonomy of algal flagella, which is being studied by both physiological and genetical techniques.

In February, Dr. Lewin participated in a three-week expedition on R/V *Alpha Helix* to study prochlorophytes in the Galápagos Islands, Ecuador. (Prochlorophytes are a unique group of algae that can be regarded as missing links between prokaryotes like blue-green algae and eukaryotes like green algae and higher plants.) In collaboration with Dr. David Smith, University of Bristol, England, Drs. Françoise Lafargue and Geneviève Ducleaux, Université Marie-Curie, France, and Dr. Andrew A. Benson, Dr. Lewin extended his earlier studies on the physiology and biochemistry of these paradoxical algae and of the ascidians with which they are normally associated in tropical waters. The pathway of carbon from seawater, through the alga to the host animal, was studied by the use of radioisotopes.

Dr. Karen Van Winkle-Swift is continuing her investigations of environmental influences on chloroplast inheri-

Pete Wilson, mayor of the city of San Diego, addresses group gathered for the dedications of the Marine Biology Building and the Carl Eckart Building that houses the Scripps Library. Seated from left to right are: Dr. Frank Press, director of the Office of Science and Technology, who delivered the main address; Dr. Walter H. Munk; Helen K. Copley, chairman of the corporation, Copley Newspapers; Chancellor William D. McElroy, UC San Diego, and Director William A. Nierenberg. The dedication was held September 21, 1977.

tance in the heterothallic green alga *Chlamydomonas reinhardtii* and on the reproductive physiology of other species of *Chlamydomonas*. A number of auxotrophic and antibiotic-resistant mutant strains of *C. monoica* have been isolated, and the first genetic analysis of a homothallic *Chlamydomonas* is presently under way. It will be of interest to determine how chloroplast genes are inherited in this species, in which there is apparently no sexual differentiation.

Graduate student Roger Chastain continues studies of algae isolated from soil samples taken throughout the western United States. The nitrogen-fixing and carbohydrate-forming properties of several strains are being examined in axenic cultures in defined media. This research is predicated on data that suggest that many soils naturally support algal growth, which in turn affects the nature of the soil.

Dr. Joan G. Stewart is investigating the intertidal benthic algae of southern California. Currently, the morphological and life history attributes of algal species that are associated in turf formations are being compared by using field-collected and laboratory thalli. A second study deals with the algal components of *Phyllospadix*-dominated sites. Although most species of algae found under or on *Phyllospadix torreyi* and *P. scourleri* are also found where *Phyllospadix* species are absent, relative abundances of the algae differ, and a few species are found only with the *Phyllospadix* spp.

Dr. Nancy W. Withers is working on the biochemistry of dinoflagellate sterols, including biosynthetic studies. A variety of zooxanthellae from various invertebrate hosts are being examined for sterol content. Additionally, she is completing a study of the pigments of marine and freshwater chrysophytes and chloromonads.

The study of the luminous fish *Monocentris japonica* by Dr. Kenneth H. Nealson's group resulted in publication of a physiological model to explain its symbiotic relationship with luminous bacteria. Many specimens of *Cleidopis gloriamaris*, another luminous fish, were collected in Australia, and are currently under study. Population analyses of free-living luminous bacteria have been obtained from Antarctica, the Caribbean, Hawaii, and southern California waters.

Studies of manganese oxidizing bacteria have established the importance of surfaces and bacterial attachment for the oxidation of manganese. The effect of both surface attachment and manganese oxidation on the morphology of these organisms has also been studied.

Marine metabolic adaptations guide the interests of biochemists in the laboratory of Dr. Benson. The role of wax ester in primary energy storage and in transfer in marine food chains was revealed by Dr. Judd C. Nevenzel's studies of lantern fish and coelacanth lipids. Wax serves as "starvation insurance" for most deep-sea creatures. It provides the needed energy for the larvae of corals as they seek new sites for colonization. Suspended in coral mucus, it provides countless small reef fishes, who feed on mucus, with a source of energy. Studies on marine mucus by Dr. James A. Christiansen are revealing its structure and methods for its quantitative measurement.

In seas most devoid of nutrient, the phosphate concentration approaches that of oceanic arsenate. Algae in such waters have learned to cope with this toxic competitor for their phosphate uptake process. They reduce and methylate the arsenic compound to produce a phospholipid in which arsenic replaces nitrogen. With radioactive arsenate, Dr. Benson's group has determined the chemical structure of the arsenophospholipid and is proceeding to study its biological properties. Nature's process for detoxication of arsentate, developed by organisms living in the sea, may provide insight into man's curious sensitivity and/or adaptability to arsenic in his diet. This insight will provide a sound basis for evaluation of the dietary consequences of arsenic compounds in marine products.

Dr. Benjamin E. Volcani and his associates continued investigating the role of silicon in metabolic processes of diatoms and mammalian cells.

Dr. Pinakilal Bhattacharyya, studying silicate transport in intact cells and membrane vesicles from lysed protoplasts of the diatom, *Nitzschia alba*, found that the energy for the transport system is provided by the sodium concentration gradient (external>internal) across the cell membrane.

It may be that this is maintained by the membrane-bound $Na^+ - K^+$ ATPase. From a study of the pH dependence of the uptake, it appears that the charged silicate ion, rather than the undissociated free acid; for example, silicic acid, is the transport species.

Dr. Claude E. ZoBell, through his continuing studies on the effects of deep-sea pressures on gas formation by anaerobic bacteria, has noted the production of appreciable quantities of carbon dioxide, hydrogen, and methane by mixed cultures of bacteria at pressures up to 600 atm. The medium, consisting of seawater enriched with various organic substrates, was inoculated with bottom sediments. Although some of the bacteria reproduced at 1,000 atm, several months incubation at 4°C was required for the appearance of gas. Gas production by soil bacteria was much more rapid at 25°C than at 4°C when compressed to deep-sea pressures. There was no evidence that gas production in closed systems resulted in an increase in hydrostatic pressure.

In the laboratory of Dr. Theodore Enns, carbon dioxide diffusing capacity has been determined in intact lobes of dog lungs. Similar determinations have been made for carbon monoxide. The information regarding exchange of gases across the gas-blood barrier obtained from these studies may be summarized as follows: Gases having low solubility in water, such as carbon monoxide and, by inference, oxygen and nitrogen, meet their major diffusion re-

sistance in the cell water of the barrier. Carbon dioxide transport on the other hand is appreciably resisted by cell membranes. Carbon dioxide transport is further decreased by carbonic anhydrase inhibition, thus showing that this enzyme appreciably facilitates transport in cell water.

Water transport experiments confirmed that water crosses semipermeable membranes at a rate proportional to differentials in activity, as predicted from physical-chemical considerations. These observations were extended to fish swimbladder tissues.

Dr. Robert R. Hessler spent this year on sabbatical at the Zoological Institute, University of Lund, Sweden. His research centered on the evolution of locomotory mechanisms in one of the most important groups of marine arthropods — the malacostracans. This work revealed two very different modes of limb movement, that resulted from the fact that one of the major lines, the Peracarida (amphipods, isopods, tanaids, cumaceans, and mysids), has evolved a limb structure that is unique among the arthropods. Dr. Hessler hypothesizes that the driving force for this change was the evolution of a ventral thoracic brood chamber. This marsupium is a key factor in the ecological success of the peracarids, but it necessitated many adaptive compromises, including major modifications of the limbs.

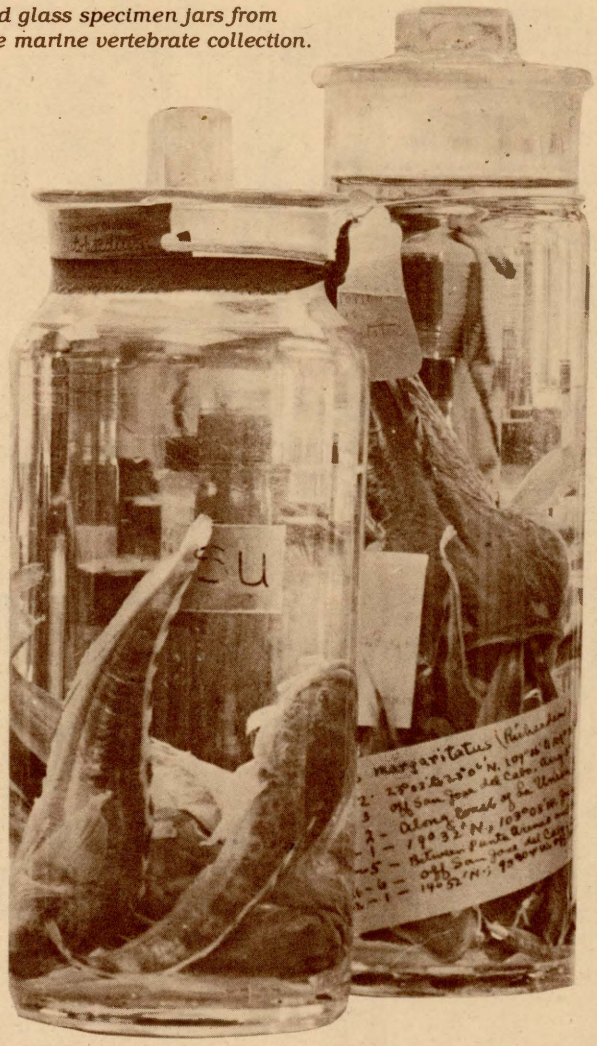
While Dr. Hessler was in Scandinavia, he had the rare opportunity of studying living examples of deep-sea crustaceans because of their emergence into shallow water at high latitudes. These observations make an invaluable addition to an understanding of the life styles of members of the deep-sea community. Many existing assumptions based on traditional morphological interpretations proved to be incorrect; for example, animals thought to swim actually burrow. This work will have immediate value in Dr. Hessler's current study of the evolution of deep-sea isopods.

Dr. Carl L. Hubbs actively continued various collaborative contributions on marine and freshwater fishes and marine mammals. The description of a remarkable new mid-water genus of macrourid fishes, appropriately named *Mesobius* (middle-living), was published in collaboration with Dr. Tomio Iwamoto, California Academy of Sciences, San Francisco. In collaboration with Dr. Robert Rush Miller, University of Michigan, Ann Arbor, Dr. Hubbs concluded a detailed study of a complex of six species of cyprinid fishes inhabiting segments of the streams of the Tampico Embayment in northeastern Mexico. The description of a relatively large mid-water fish, *Parabassogigas*, was completed with Dr. W. I. Follett, California Academy of Sciences. Several joint studies on the hagfishes of the world were brought to or near completion; thus markedly increasing the knowledge of this primitive group. A long-continued study of the worldwide epipelagic fish family, Scomberesocidae, in collaboration with Robert L. Wisner, is completed.

Dr. Richard H. Rosenblatt has continued his investigations of genetic differentiation and evolutionary rates of New World tropical marine fishes. Results to date indicate that rates of morphological and genetic differentiation have not been closely coupled. Caribbean and eastern Pacific populations indistinguishable morphologically have been found to be as differentiated genetically as good morphological species. Calculations of time of separation, based on genetic differentiation between populations, agree well with the time of closure of the Panama portal connecting the oceans.

Dr. William A. Newman's research was devoted to studies on the biogeography of barnacles of the tropical Americas and of high latitudes of the Southern Hemisphere. This spring Drs. C. Eve Southward and Alan J. Southward, Plymouth Laboratory, England, joined Dr. Dennis

Old glass specimen jars from the marine vertebrate collection.



Hedgecock, Bodega Marine Laboratory, California, and Dr. Newman aboard R/V *Alpha Helix* in Panama for work along the shore while returning to San Diego. Samples of barnacles and other crustaceans were frozen and fixed, for enzyme as well as traditional taxonomic analyses. The purpose of the work is to be able to distinguish between short- and long-range populations in the eastern Pacific and to determine their relatedness to comparable populations in the Caribbean; populations that could become reunited should an unbarriered sea-level canal be built in the panamic region.

Dr. Newman's work on barnacles of the Southern Hemisphere included the discovery of three new species from shallow water, one of which is the only acorn barnacle known from Antarctic shores. These pan-austral forms evolved no earlier than the Oligocene, and thus their distributions are attributable to dispersal by oceanic currents, rather than to the major breakup of Gondwanaland at the end of the Cretaceous, as many contemporary biogeographers would like to believe.

Graduate students in Dr. Newman's laboratory continue research on a variety of subjects. Stephen Piper made significant progress in the laboratory and is now preparing for the field aspects of his studies on physiological adaptations of chitons in relation to their spatial and temporal distributions in the intertidal zone. Michael Huber joined the R/V *Alpha Helix* cruise to collect crustacean symbionts of hermatypic coral for his studies of their effectiveness in protecting corals from predators.

Research of Dr. Kenneth L. Smith has dealt with both the deep-sea benthic and mid-water communities in an

NANCY MANCINO

Dr. Kenneth L. Smith, left, and G. Allen White guide free-vehicle grab respirometer as ship's crane lowers it to deck of R/V Thomas Washington.

attempt to resolve the energy flow through this complex ecosystem.

Free-vehicle grab respirometers were used to measure deep-sea benthic community metabolism in the eastern North Pacific and no significant difference was indicated in total oxygen uptake between 1,200 m and 3,800 m as a result of the influence of eutrophic California Current system overlying both stations.

Three species of abyssopelagic animals, previously presumed to be benthic, were caught up to 730 m above the abyssal floor in the central and eastern North Pacific by the use of free-vehicle systems. The presence and gut contents of these animals in mid-water suggest active two-way exchange of food energy between pelagic and benthic communities.

Respiration rates of another ubiquitous abyssopelagic animal, the amphipod *Paralicella capresca*, were measured *in situ* in the northwestern Atlantic. Two distinct respiration rates were measured, an active rate comparable to that of shallow water amphipods and a resting rate two to three orders of magnitude lower. Rates seem associated with periods of food searching and dormancy.

In Dr. George N. Somero's laboratory, adaptations of enzymes to the physical and chemical conditions of the marine environment received continued study. Pressure-adaptive differences in enzymes of congeneric species differing in depths of occurrence were discovered by Dr. Joseph F. Siebenaller. This observation suggests that protein adaptation is an important component of adaptation to life at depth. Graduate students Paul H. Yancey and R. David Bowlus completed studies designed to determine the basis of organic osmotic solute accumulation in marine invertebrates and elasmobranchs. Bowlus showed that invertebrates accumulate a family of nitrogenous compounds, principally low molecular weight free amino acids, which have non-perturbing effects on enzyme structure. Yancey found that marine elasmobranchs accumulated solutes with antagonistic influences. Urea tends to inhibit protein function, but the other nitrogenous solutes found in elasmobranch cells, notably trimethylamine oxide, betaine, and sarcosine, offset these urea effects.

Respiration, nitrogen excretion, and chemical composition of one of these animals, the rattail *Coryphaenoids armatus*, were measured *in situ* in the northwestern Atlantic. Metabolic rates follow expected increase as a fractional power of body weight, but they are two orders of magnitude lower than rates in comparable shallow water species. Both metabolic rate and chemical composition suggest adaptation to a food limited deep-sea environment.

Dr. Denis L. Fox continued his researches and writing on the character of animal biochromes and the comparative metabolism of ingested carotenoids.

Ocean Research Division

The Ocean Research Division (ORD) is a broadly interdisciplinary division that includes the research of individual investigators and research units in such disparate fields as marine biology and physiology, marine chemistry, and physical oceanography.

Several nearshore ecology projects are continuing in Dr. Paul K. Dayton's group. They carried on long-term experimental studies of California kelp forests, and have recently emphasized dispersal biology and demographic patterns of kelp and their epiphytes. Dr. Brian D. Keller has been studying the community ramifications of sea otters of central California. The group is now analyzing data from their Antarctic research program, through which they investigated sponge and soft-bottom communities.

In the area of mathematical demography, Dr. Daniel Goodman has been investigating the maximum yield prob-

DR. MIA J. TEGNER

Dr. Mia J. Tegner's ecological studies were used to design the first seeding experiments of the Experimental Abalone Enhancement Program (EAEP). Hatchery-reared juvenile red abalones were seeded into different experimental habitats on Santa Rosa Island. Four months later, recovery rates and growth were used to rank the various habitats tested. The EAEP seeks to determine the scientific and economic feasibilities of enhancing abalone populations in depleted areas.

lem in harvested populations. For an unselective harvest, he found a simple formula giving the population density at which the sustained harvest rate is maximal. The optimal population size computed by this method is generally much larger (closer to carrying capacity) than traditional prescriptions based on models with less complete representation of age structure.

Dr. Goodman has been working on methods for the detection and analysis of multispecies patches in spatial and temporal sequences. The techniques have thus far been applied successfully to some transects of terrestrial vegetation and some time series of coastal phytoplankton abundance. In the area of niche theory, the application of some multivariate correlation techniques to a set of records of phytoplankton abundances and concurrent physical measurements, has shown that in principal the physical variability is rich enough in dimensions to allow a distinct set of conditions to be defined for each major bloom species.

The experimental program now in progress in Dr. James T. Enright's laboratory represents an investigation of the sensory system that mediates behavioral responses of the sand crab, *Emerita*, to very small increases in hydrostatic pressure.

Dr. Enright completed work that proposes a unified conceptual framework for interpretation of experimental data on the sleep-wake cycle of birds and rodents. The proposed model demonstrates that a very precise oscillator can be constructed by coupling within an array of very sloppy, erratic, relaxation-oscillator components. Such systems, which incorporate elementary assumptions derived from neurophysiology, have been simulated by Monte Carlo-type computer techniques.

Many previously unexplained aspects of the experimental data on entrainment of circadian rhythms can be accounted for by the assumption that light exerts a tonic influence on a system threshold, thereby modulating intra-ensemble coupling. The sign of this effect (+ or −) determines whether the organism is nocturnal or diurnal. One of the most interesting properties of such systems is their capacity to "learn": persistent modifications of system performance can be induced by entrainment regimes that modify the phase relationships among constituent oscillators, without any change in the properties of the components or the nature of the linkage between them. This behavior imparts to the system a kind of history dependence that involves information stored in temporal relationships, rather than in modification on intrinsic characteristics of the structure of elements.

Scientists in the laboratory of Dr. Walter F. Heiligenberg studied the detection and discrimination of electric signals in electric fish. These animals respond to electric organ discharges (EODs) of conspecifics in the context of "social communications." They evaluate feedback from their own EODs in order to assess their environment by a process called "electrolocation." Studies performed in collaboration with Dr. Richard A. Altes revealed that the gymnotoid electric fish, *Hypopomus artedi*, discriminates between electric stimulus pulses with identical spectral amplitudes but different spectral phase functions. Behavioral results can be explained on the assumption that electroreception is based on a linear filter, approximately matched to the species' EOD. The impulse response of the appropriate matched filter, in fact, resembles the known impulse response of the electroreceptors involved.

Investigations of the geochronological, biological, and archeological applications of amino acid racemization and decomposition reactions are being continued by Dr. Jeffrey L. Bada and co-workers. Following excavations at a prehistoric Indian site located near UC San Diego, a skeleton that was estimated to be 8,000 years old on the basis of aspartic acid racemization dating was submitted for a radiocarbon analysis. The resultant date of 8,360 ±75 years corroborated the racemization date, and both dates have documented the oldest milling stone (or metate) burial in North America. The concordance between the two dating methods at this coastal site lends support to the racemization dates of 20,000 to 50,000 years previously assigned to other paleo-indian occupations in coastal southern California.

DR. LANNA CHENG

Crab, Grapsus tenuicrustatus

Racemization analyses on fossil mollusc shells, derived from interglacial terraces in San Diego County, are providing ages for previously undated localities. There is strong correlation with high sea stands dated in other parts of the world by isotopic and radiometric methods. Estimates of relative rate of uplift and activity of the faults can be made by identifying terraces of the same age in faulted areas.

Graduate student Philip Ming-Yung Shou has participated in the development of a new geochronological method that involves the decomposition of hydroxy amino acids in foraminifera and deep-sea sediments.

Studies are also continuing on the amino acids dissolved in oceanic waters. Samples have been taken off the coasts of California and Peru and in the North Pacific Gyre off Hawaii. The concentrations of amino acids are the same in all three areas. The extent of racemization of alanine increases with the distance from shore in surface waters and with depth.

Dr. Patricia M. Masters is investigating the occurrence of aspartic acid racemization in tissues from living humans. After her observation that D-aspartic acid accumulates in human tooth enamel and dentine as a function of age, it was predicted that any metabolically stable protein maintained at mammalian body temperature would be subject to racemization. Dr. Masters has demonstrated that racemization is taking place in proteins of the ocular lens and that there is a correlation with one form of cataract. The physiological consequences of this reaction could contribute to the aging process in long-lived mammals.

Work is also being carried out on the teeth and/or lenses of marine mammals in order to establish ages in animals of interest to population biologists and others who study populations of endangered species.

Dr. Tsaihwa J. Chow is studying the occurrence of barium in oceanic basalts. The eruption of basalt on oceanic ridges, seamounts, and island arcs is the major transport mechanism involved in the transfer of trace elements from the upper mantle to the oceanic crust. Coupled with other "incompatible" elements, the barium content of oceanic basalts can be used as a tracer in understanding the nature of the source, the melting history, and the evolution of magmas in and around the Pacific Basin.

Barite, which is a barium sulfate mineral, is commonly used as a weighting agent in oil-well drilling mixture; therefore, the distribution pattern of barium in seawater and sediments near drilling sites may provide an indication of anthropogenic chemical contamination from oil drillings. Barium contents of southern California coastal waters and sediments have been examined in order to monitor the possible pollution caused by offshore drilling operations.

Dr. D. John Faulkner's research has been directed toward the structural elucidation of biologically active chemicals from Caribbean marine organisms, particularly sponges, which were collected during a research cruise to Belize on R/V *Alpha Helix*. Half of the sponges collected produced chemicals that were toxic or inhibited the growth of bacteria. Several unusual antibiotics were characterized. A comparison of the secondary metabolites of two opisthobranch molluscs that contain functional chloroplasts resulted in the isolation of two groups of chemical structures that could be related through a photochemical rearrangement.

At the Mt. Soledad Radioisotope Laboratory, Dr. Robert C. Finkel has been using the distribution of uranium and thorium series radioisotopes as a geochemical tool for investigations of earthquake prediction techniques, of basalt seawater interactions, and of the marine chemical cycle of trace elements.

In the first study, uranium concentrations of $^{234}U/^{238}U$ isotope ratios are being determined in water from springs and wells associated with several active fault systems in southern California in order to assess the possible utility of these isotopes as earthquake precursors. Preliminary results have shown that the uranium concentration varies by almost three orders of magnitude in the samples measured and that the $^{234}U/^{238}U$ isotope ratio varies from 0.9 to 2.4.

In a second study, Dr. Finkel has been working with Dr. J. Douglas Macdougall to understand the nature and extent of basalt seawater interactions, with particular emphasis on the marine chemistry of uranium. Measurements have shown that uptake of uranium by basalts is a common occurrence. The $^{234}U/^{238}U$ isotope ratio measurements indicate that manganese crusts, fine grained crystalline interiors, and palagonite rims all behave quite differently with respect to uranium uptake. The limited sample set measured to date seems to indicate that continued interaction with seawater may be more common for basalts exposed on the sea floor than for those buried by sediment cover.

The marine chemistry of lead and polonium is the focus of a third study. As a participant in the GEOSECS Indian Ocean Expedition, Dr. Finkel collected water samples from stations along the western edge of the Indian Ocean. These samples are currently being analyzed in collaboration with Drs. Harmon Craig and Yu-chia Chung for the ^{210}Pb and ^{210}Po concentrations in both particulate and dissolved phases. The measured geographical and vertical distribution of lead and polonium isotopes will provide information about both large-scale oceanic circulation and transport mechanisms of chemical species in the oceans.

Also at the laboratory, Dr. Theodore R. Folsom continues his review of radioactive tracers concentrated in Pacific albacore tissues. He is gaining a better understanding of mechanisms that control the fate of six different elements that 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 unrelated 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. However, a recent review of more than 3,000 samples of cesium-137 surface seawater analyzed over the past two decades suggests that residence time near the sea surface is still longer than is to be inferred from fish monitoring alone. These data disclose lateral concentration gradients that indicate positive advection into the fish-sampling area had taken place during the sampling period.

Scientists at the Mt. Soledad Tritium Laboratory continued their investigations on the changing distributions of tritium in the world oceans. Recent emphasis was placed on tritium distributions in bottom water in the Weddell Sea. Measurements show that bottom-water tritium concentrations are highest near the continental shelf break and lower in the central Weddell Basin. These results support theories in which bottom water forms near the continental shelf break and flows in a clockwise manner around the Weddell Basin. From the tritium data a production rate of 6×10^6 m^3/sec is obtained for classical Antarctic Bottom Water.

Samples were also collected in conjunction with the Ross Ice Shelf project. Water taken from under the shelf at the J-9 drilling site was found to have tritium concentrations similar to surface water in the open Ross Sea. This indicates that water under the shelf is rapidly flushed by waters from the open sea.

Surface tritium data from the Caspian Sea were analyzed to estimate the turnover rate of Caspian Sea surface water. It was found that within the uncertainty limits of the data, no turnover occurs. This indicates that the persistence of pollutants in the Caspian Sea can be unusually long. The tritium measurements gave no indication of any dumping of radioactive waste or material into the sea.

In Dr. Joris M. Gieskes' laboratory, research continued on the geochemistry of interstitial waters and sediments obtained by the Deep Sea Drilling Project (DSDP).

Dr. Gieskes directed his attention to X-ray fluorescent analysis of solids and ocean particulates.

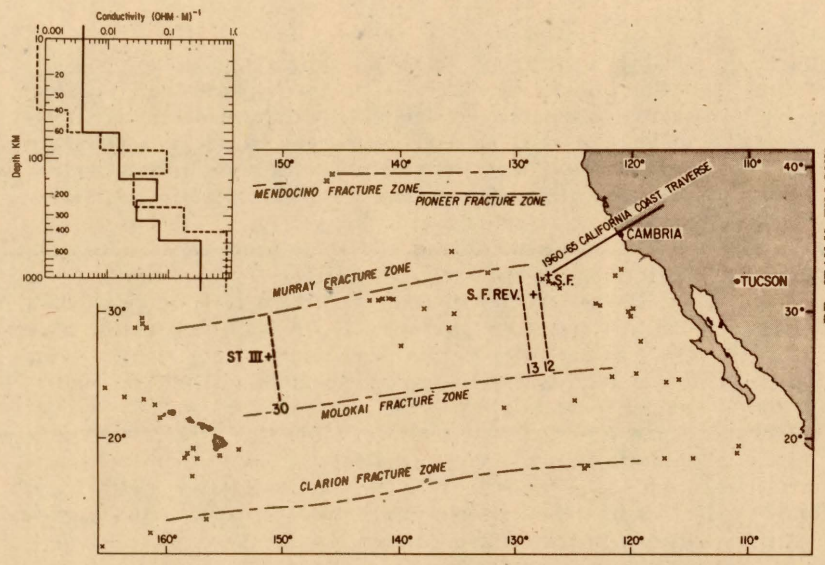
Graduate students in his laboratory did research in a number of areas, including the transport processes in marine sediments, dissolution kinetics of amorphous silica in aqueous solutions, and evaluation of data on the oceanic CO_2 system from 35°N. Also a free-vehicle, benthic-boundary-water and interstitial-water sampler was constructed.

Dr. Charles D. Keeling and co-workers continued their measurements of atmospheric CO_2. They now have a twenty-year data record at Mauna Loa, Hawaii, and the South Pole that reveals a persistent increase, attributed to the combustion of the fossil fuels: coal, petroleum, and natural gas.

The GEOSECS (Geochemical Ocean Sections Study) operations group occupied forty-five geochemical stations during the GEOSECS Indian Ocean Expedition. They took samples of carbon-14, helium, tritium, radium-226 and radium-228, lead-210, silicon-32, and barium, and collected particulates as well as the standard hydrographic parameters. Measurements were made of continuous profiling temperatures, salinity, oxygen, and particulate concentration. In addition, the group has participated in work with three other institutions.

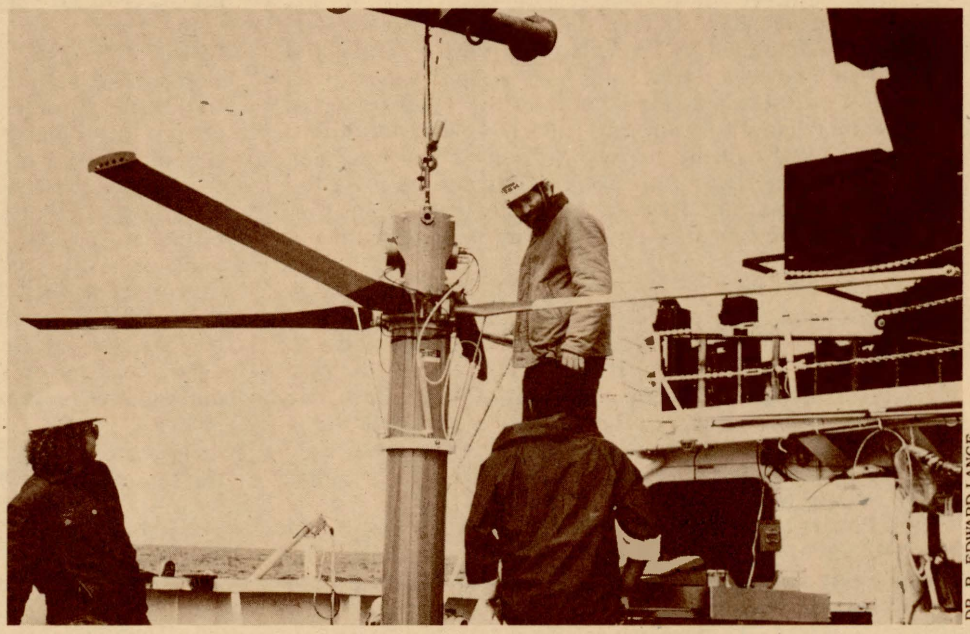
Special instrument development by the operations group included the adaptation of intelligent terminals to shipboard instrumentation, including automated titrators and the display of parameters computed from basic data obtained from CTD (Conductivity-Temperature-Depth) profilers.

Dr. Knox continued to adapt moored current-meter techniques to locations and studies not accessible to conventional methods. In the equatorial Indian Ocean, north of the Seychelles, he has continued collection of data from light moorings serviced by small charter vessels. In the equatorial Pacific, along 150°W, valuable engineering experience was gained when he and Dr. Russ E. Davis set and



DR. JEAN H. FILLOUX

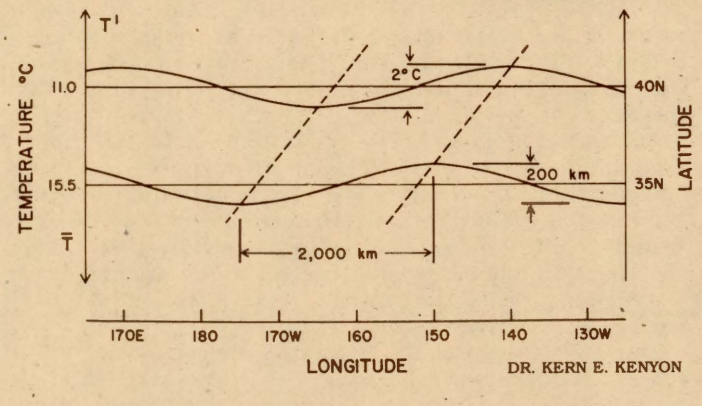
Positions of magnetotelluric sites, "ST III" and "S.F.Rev." The dashed lines between Murray and Molokai fracture zones represent magnetic reversal anomalies, and their numbering is an indication of the age of the Pacific Plate: 72 m.y. for anomaly 30 and 30 m.y. for 12. Graph in upper left illustrates the electrical conductivity distribution with depth in terms of layered structures: continuous line for ST III; dashed line for S.F.Rev.



DR. R. EDWARD LANGE

Bill P. Johnson, upper center, Jack C. Lucas, right, and William Fleck, left, aboard ship, inspect velocity microstructure recorder prior to its launch.

Sea-surface temperatures in the eastern North Pacific.



DR. KERN E. KENYON

recovered two surface moorings designed to withstand strong currents.

Dr. Jean H. Filloux and his group are expanding their magnetotelluric exploration of the earth beneath the sea floor. Recently inferred electrical conductivity profiles at two North Pacific stations, "ST III" and "S.F.Rev.," were compared. The high conductivity tongue between 140 and 230 km depth for ST III and 85 and 130 km for S.F.Rev. are interpreted as representing the asthenosphere. The deeper lithosphere-asthenosphere interface and lower asthenosphere conductivity at ST III are consistent with the older age of the Pacific Plate, namely 72 m.y. against 32 m.y. at S.F.Rev.

Dr. R. Edward Lange and Bill P. Johnson used a freely falling vehicle in the Mixed Layer Experiment (MILE) to obtain the time-evolution of storm induced mixing in the Pacific Ocean. In another experiment in the North Atlantic they used a modification of the standard expendable bathythermograph recording system. They completed a survey on small lateral scales of the fine-structure temperature profiles of the upper ocean. Dr. Lange and Johnson showed that over distances of 15 nautical miles, isotherms exhibited lateral slopes of order 80 m. Using this same recording technique, they obtained fine-structure records of the upper 800 m of the ocean to a metrical resolution of 10 cm, with 100 micro-degree temperature resolution. They found that near high isotherm slopes, fine structure increased in intensity, and there appeared to be a downward propagation of persistent fine-structure features within the temperature field suggestive of mixing and internal wave generative processes.

Dr. Kern E. Kenyon analyzed hydrographic data from California to Japan at 35°N and 30 years of climatological sea-surface temperature data from mid-latitudes in the North Pacific. He is seeking an explanation for permanent longitudinal variation in surface temperature in the eastern Pacific, in terms of its implications for the near-surface ocean circulation, for air-sea interaction, and eventually

for long-range weather forecasting for the United States. The surface mixed-layer structure at 35°N suggests the best interpretation of the east-west scale is 4,000 km centered about the longitudinal temperature maximum.

Dr. Jason H. Middleton and Dr. Theodore D. Foster, UC Santa Cruz, organized the 1978 International Weddell Sea Oceanographic Expedition to the southwestern Weddell Sea. Altogether 118 CTD stations were occupied in a region where active frontal zone mixing, which leads to Antarctic Bottom Water (AABW) formation, has been previously observed. In addition five moorings, each with two current meters and two acoustic releases, were deployed at 16 km spacings in a line perpendicular to the bottom contours. Analysis of the data from this cruise is expected to provide further insight into the mixing processes leading to AABW formation.

NORPAX (North Pacific Experiment) is a long-term, multiinstitutional study of mid-latitude air-sea interactions. The studies at Scripps are headed by Dr. David L. Cutchin.

A three-month NORPAX Shuttle Experiment this winter, which was conducted by Dr. William C. Patzert, consisted of a network of ocean/atmosphere observing systems in a strip of ocean between Hawaii and Tahiti. Measurements were made from ships, aircraft, moored instrumentation, satellite-tracked drifting buoys, and island stations. The shuttle experiment was done to obtain descriptions of the time- and space-scales of ocean variability with application to the design of a large-scale/long-term ocean monitoring network.

Drs. Patzert and Tim P. Barnett were principal investigators of the aircraft-monitoring component of the shuttle experiment that involved 13 round-trip flights between Honolulu and Tahiti. The primary measurement program aboard these flights was the collection of AXBT (airborne expendable bathythermograph) data along N-S flight tracks. These data will be used to provide the large-scale background from which the other data sets can be objectively interpreted.

Drs. Robert L. Bernstein and Warren B. White continued the TRANSPAC project, which requires that samples be taken along the trade routes from the United States to Japan aboard commercial ships. To monitor surface flow in this area, Gerard J. McNally uses groups of 20-40 satellite-tracked drifting buoys. From wind stress and surface heat flux calculations, Drs. Bernstein and White have shown that in the eastern North Pacific the horizontal mixing of heat, salt, and momentum by mesoscale eddies is negligible, but thermohaline processes have a surprisingly large effect on the formation of thermal anomalies in the upper 500 m of the open ocean. McNally and Dr. Stephan E. Pazan have found that surface currents appear to move 15-30° to the right of the wind and not the 45° proposed by steady state Ekman theory. The commonly assumed dependence of the depth of the thermocline on the convergence and divergence of the wind-driven currents appears doubtful. Thus, the field experiment suggests that many of the assumptions important to the classical wind-driven circulation theory are questionable, while the influence of thermohaline processes (neglected in the classical theory) are emerging as dominant in modifying the strength and location of the North Pacific Current.

Because precipitation is an important element of climate, Dr. John O. Roads and Daniel R. Cayan have been investigating the use of vertical velocity in the atmosphere as a potentially more reliable indicator and predictor of precipitation than the standard height fields. They have found agreement between computed vertical velocity and observed precipitation over most of the Northern Hemisphere. It appears that monthly mean atmospheric data may be used satisfactorily to compute a monthly mean vertical velocity, in spite of the nonlinear equations involved.

The Climate Research Group encompasses several interrelated projects concerned with enhancement of short-term (a month to a year or two) climatic forecasting techniques. The primary emphasis is upon understanding the stabilizing influence the oceans have on the large-scale atmospheric circulation patterns.

The severe winters of 1976-77 and 1977-1978 were reasonably well predicted by both Dr. Jerome Namias and Dr. Barnett. Two different prediction techniques yielded similar general patterns. The technique used by Dr. Namias involves the projection of the Pacific Ocean water temperatures into an atmospheric teleconnection model for the subsequent temperature predictions over North America. The technique used by Dr. Barnett is a quantitative analog method of inferring future climates from past climate states. This method uses the new ideas of a climate state vector and "climate particle" that carries in its structure the equivalent of 20-million pieces of data on the evolution of past climates.

Dr. Barnett, with Klaus Hasselmann, Max Planck Institute of Meteorology, West Germany, has shown that prediction of El Niño in the tropical Pacific is feasible up to a year in advance. Furthermore, properties of the central Pacific Ocean, including its surface temperature, as well as properties of the Intertropical Convergence Zone, are also predictable six to twelve months in advance. The predictability studies show that variations in the wind field in the western Pacific are the best predictors for the above quantities, while ocean surface variables are rather poor predictors of variability in the wind field. It appears that in the tropics the oceanic responses are largely caused by atmospheric force.

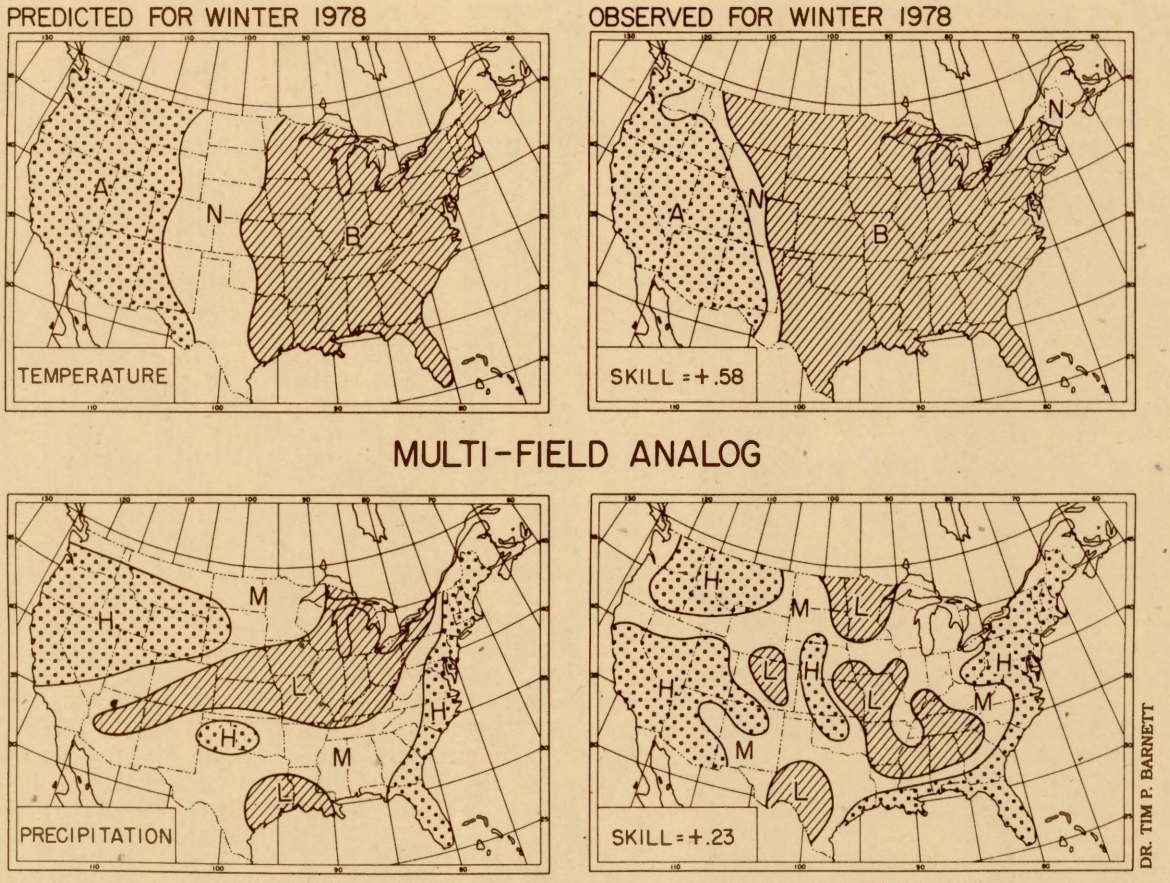
Dr. Roads's intermediate dynamical atmospheric circulation model has been modified, refined, and debugged and is installed and operating at the National Center for Atmospheric Research, Boulder, Colorado. He has completed the first control run on his dynamical circulation model as well as the first experiments on sea-surface temperature anomalies and snow albedo. Based upon the preliminary results, several alterations have been made to the equations and a second set of runs is being produced.

The identified climate regimes of 1947-1957, 1958-1970, 1971-1976, and 1977-1978 have been time-averaged separately, and comparisons of the patterns indicate strong, coherent differences. Further analysis by Dr. Namias is underway to determine why climatic patterns can persist for these long periods and why they change abruptly.

Analysis of empirical orthogonal function fields for several parameters over the Northern Hemisphere has been completed by Dr. Barnett. The first results indicate that the variability of the Northern Hemisphere air temperature field has undergone substantial increase since 1963. Thus the assertion that climate has become more variable in the last decade appears substantiated if one is willing to equate surface-air temperature with "climate."

The Shore Processes Study Group is investigating physical and sedimentary processes in the nearshore environment. Research objectives include field and laboratory measurements of waves, currents, wind, and the resulting sediment transport in the coastal zone, and use of these data to identify and study the basic mechanics of nearshore currents, surf zone dynamics, and sedimentary processes.

Significant research projects carried out this year include the analysis of data obtained in March 1977 during the National Aeronautics and Space Administration's Seasat West Coast Experiment. Dr. Robert T. Guza and graduate student Michael M. Freilich have studied nonlinear energy trransfers in shoaling wave spectra and the distribution of velocity variance with frequency in the surf



Successful experimental prediction of temperature and precipitation for the 1977-1978 winter is shown side-by-side with same patterns observed during the season. Predictions made by the Climate Research Group.

zone. Graduate student Steven S. Pawka has used data from the experiment to study the island shadowing effects on wave climate of local beaches. Drs. Douglas L. Inman and Reinhard E. Flick and graduate students have analyzed suspended and total sediment transport measurements in an effort to describe its relation to wave and bore characteristics in the surf zone.

Graduate student Scott A. Jenkins is investigating both theoretically and experimentally the forces on submerged objects under the influence of waves. Measurements show the previously unrecognized importance of wave-induced circulation on the forces on a submerged sphere.

Dr. David G. Aubrey has analyzed a five-year-long set of beach profile data and simultaneous wave data from Torrey Pines Beach, California. The principal result was a model relating beach profile changes to wave climate changes that used the method of linear statistical predictors. Dr. James A. Bailard made basic measurements of the flow of granular fluids, and compared his observations to recent theories of granular mechanics. An application of the results currently under study is the development of a bedload sediment transport model based on momentum principles instead of previously accepted energy arguments. Dr. Flick made a comprehensive laboratory study of monochromatic and biharmonic wave shoaling. Theoretical results show the existence of a uniformly valid approximate nonlinear theory for wave shoaling from deep to shallow water. Dr. Gregory W. Geehan has completed a four-year study into the dynamics of long-shore intertidal sand bars in the Gulf of California.

Drs. Inman and Bailard and John D. Powell recently completed a field study of a crater-sink sand bypass system at Agua Hedionda Lagoon. The lagoon is used by San Diego Gas and Electric Company as a generator cooling water reservoir. Tidal flow and waves cause littoral sand to accumulate in the lagoon, thus necessitating expensive yearly dredging. The objective of the study is the designing and testing of lower cost innovative techniques for sand management in lagoons and harbors, based on the principle of working with natural processes, not against them.

Results of the continuing study of sediment problems and cures at Navy port facilities by Drs. William G. Van Dorn and Scott S. McElmury include: 1) the observation that during this near-record California rain year salinities in Mare Island Strait remained so low (< 5‰) that the abnormal sediment burden was well mixed, instead of flocculating and precipitating as a tidal suspensate, as was observed in last year's drought; 2) successful redesign of a linear jet array to protect a submarine berth by resuspending daily sediment accumulations, and 3) design of a movable membrane barrier 10 m high by 90 m long to protect a finger pier berth by preventing the bulk of tidal sediment exchange with the adjacent strait.

Drs. Clinton D. Winant and Robert W. Severance, Jr., and graduate student Alan W. Bratkovich have been carrying out an extensive ongoing field study of coastal circulation and temperature fluctuations off Del Mar and San Onofre, California. These measurements will provide background information on the current and thermal regime in the area as well as basic data for dynamical studies and satellite overflight data comparisons.

Marine Physical Laboratory

The Marine Physical Laboratory's program of ocean acoustics, marine geophysics, sea-floor studies, and ocean technology included investigations at sea in such diverse locations as Indonesia, Japan, Hawaii, the East Pacific, and the Red Sea.

An early highlight of the year was the observance of the 15th anniversary of R/P FLIP (*FL*oating *I*nstrument *P*latform). FLIP was originally constructed as a stable platform from which scientists measured the effects of the ocean medium on the directional stability of underwater acoustic signals. Scientists continue to use FLIP for a variety of unique measurements of the ocean environment.

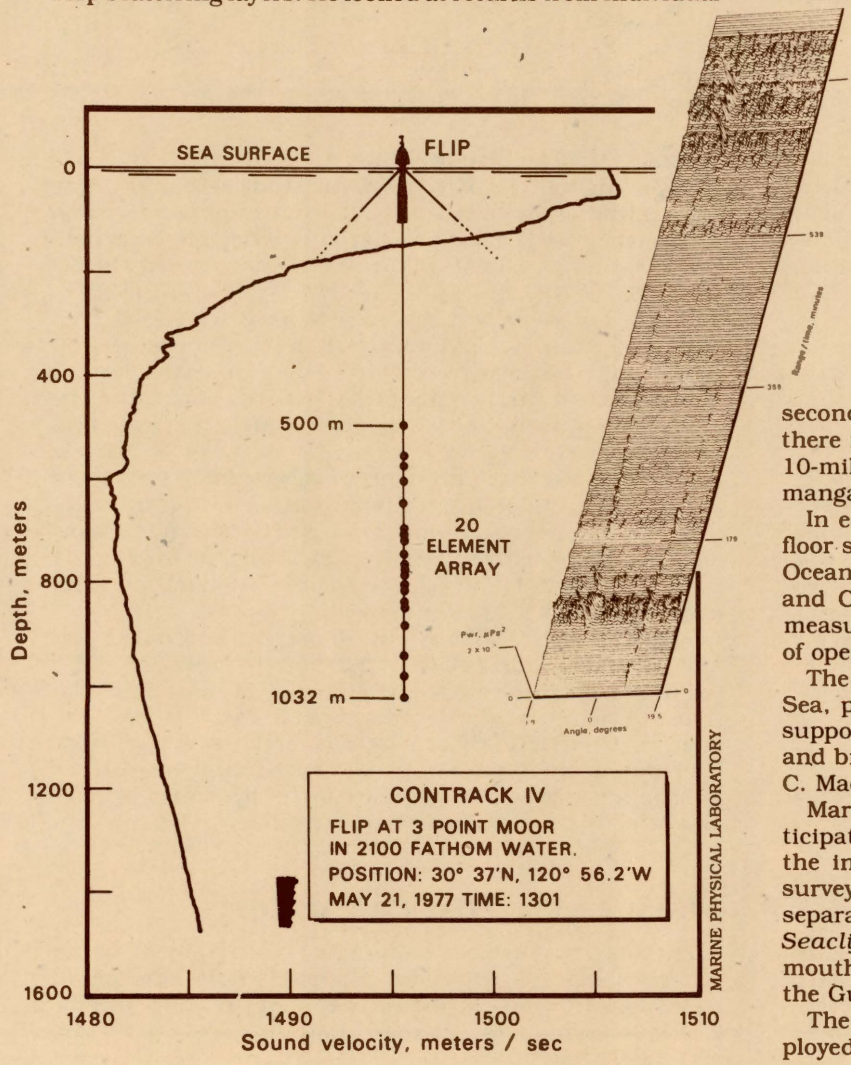
A vertical hydrophone array deployed below FLIP has been used by Dr. Frederick H. Fisher and Frank M. Phelan to resolve multipaths in long-range sound propagation in order to determine how fluctuations in the medium affect individual multipaths. Preliminary results show a display of the vertical angles of arrival that portray the individual multipaths as a function of range.

In using 0.1 msec pulses of 87.5 kHz sound to measure the thickness of layers of acoustic scatterers, Dr. Fisher and Earl D. Squier used a two minute long, computer expanded plot of analog data obtained at a depth of ~160 m. The computer expanded data represent only a small part of the data in which large unidentified clouds of scatterers are also seen.

In May FLIP was used in acoustic studies of the deep ocean west of San Diego. Drs. Gerald B. Morris and Robert C. Tyce used the 532-m vertical hydrophone array to study the directionality of ambient noise at low frequencies. By changing the depth of the array, variation in the directionality was observed and linked to the position of the array with respect to the channel. On the same trip, Dr. G. Thomas Kaye used the 87.5 kHz sonar to investigate acoustic scattering from biota and to detail behavior of the deep scattering layers. He looked at returns from individual scatterers, and concluded that it may be possible to estimate not only the number of scatterers as functions of depth and time, but also the size distributions of the scatterers based upon the amplitudes of returns. In addition, these scatterers appear to be excellent tracers of internal wave activity. A tracking program has been developed to evaluate this echo sounder as a remote sensing device of these motions.

The physics of the generation and propagation of upper ocean internal waves continues to be investigated by Dr. Robert Pinkel. Through the use of the 87.5 kHz, narrow beam Doppler sonar mounted on FLIP to remotely sense the water velocity field, the sound scatters off zooplankton in the upper ocean; they are assumed to be drifting with the water motion. From the Doppler shift of the returning sound, the component of water velocity parallel to the beam can be obtained simultaneously at many ranges. The sonar was mounted on FLIP at 50 m depth, slanted downward from the horizontal. Wave motions of frequency near 1 cycle per day (near vertical) dominate the velocity field. A new Doppler sonar is currently being constructed that will have a more precise beam pattern and greater power than the prototype. When tests of this sonar are completed, several more will be constructed; they will enable water velocity to be measured in several directions simultaneously.

The Deep Tow Group under Drs. Fred N. Spiess and Peter F. Lonsdale conducted Leg 1 of the Indomed cruise aboard R/V *Melville* in the fall. The first survey site was near the Siqueiros tranform fault of the East Pacific Rise near 9°N, where scientists studied the deposition of metalliferous sediments derived from hydrothermal emanations. The second survey site was in the Guatemala Basin, where there is a thin superficial layer of oxidized sediment on a 10-million-year-old crust and an unusual occurrence of manganese nodules in a hemipelagic environment.



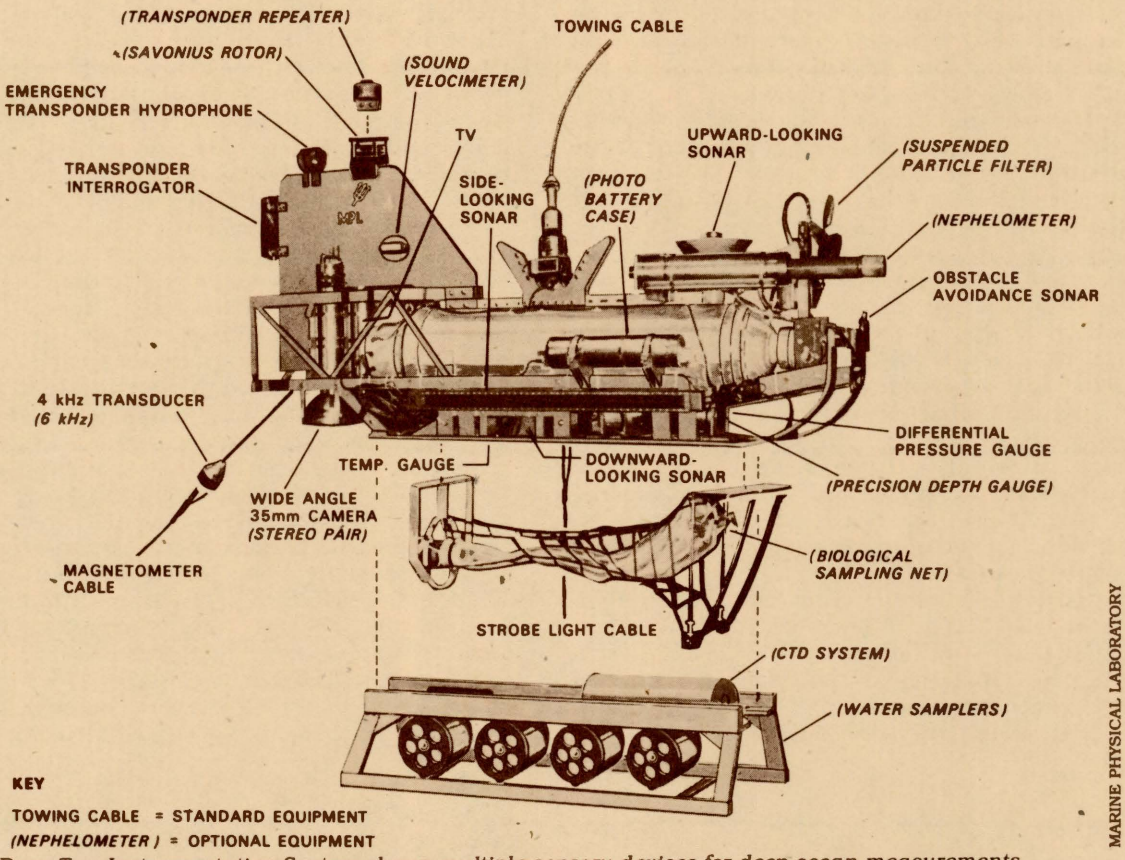
FLIP at three point moor with 20 element vertical array. Inset at right is plot of vertical distribution of energy received by the array of 400 Hz sound at ranges from 190 to 210 nm.

In early 1978, the Deep Tow Group conducted two seafloor survey operations in the central and western Pacific Ocean for the U.S. Naval Oceanographic Office. Drs. Spiess and Carl D. Lowenstein applied the fine-scale scientific measurement capabilities of the system to the development of operational procedures for the U.S. Navy.

The Deep Tow Group, aboard R/V *Melville* in the Red Sea, provided multiple-sensor measurement capability in support of geophysical studies of new bottom structure and brine pools conducted by Drs. Lonsdale and Kenneth C. Macdonald.

Marine geophysical studies included an increasing participation in the use of manned submersibles to follow up the initial investigations conducted with the Deep Tow survey system. Dr. Lonsdale made several dives on two separate occasions in the U.S. Navy's deep submersible *Seacliff* in the areas of the East Pacific Rise located in the mouth of the Gulf of California and farther up the gulf in the Guaymas Basin.

The unique submersible acoustic array ADA was employed on five operations at sea off San Diego under the



Deep Tow Instrumentation System shows multiple sensory devices for deep ocean measurements.

direction of Dr. Victor C. Anderson. ADA was proven successful through array calibrations and deep-water mooring operations, conducted consecutively in water depths of 1,010, 1,830, and 3,660 m. Measurements of the detailed structure of ambient noise in the ocean are now possible with much greater precision and discrimination than ever before.

The group directed by Drs. George G. Shor, Jr., and Russell W. Raitt concentrated on analyzing data gathered in the intensive studies of southeast Asian continental margins under the SEATAR (Studies of East Asian Tectonic and Resources) International Decade of Ocean Exploration program. They also designed and constructed new, deep-moored, digital-recording hydrophones for studies of sound transmission in marine sediments. Analysis of the remainder of the continental margin geophysical data is continuing. Graduate student Robert M. Keickhefer made a two-month field study of earthquake seismicity, in cooperation with Indonesian investigators, in the area of Sumatra near to the location of last year's marine geophysical studies.

Dr. Fisher invented a Laser Sand Detector to measure suspended sand in the surf zone. The principle that sand depolarizes light and bubbles do not has been successfully demonstrated in the laboratory, and offers promise for development of means for practical application in the sea.

Continuing investigations of the causes of sound absorption in the ocean have included electrical conductance studies of pressure effects on chemical equilibria. Dr. Fisher and A. Peter Fox have completed a study of divalent sulfates using the Fuoss/Hsia/Fernández-Prini conductance equation. The molal dissociation constants for $CaSO_4$, $MgSO_4$, $CoSO_4$, and $NiSO_4$ increase by a factor of 1.9 (within 5 percent) for a pressure change of 2,000 atm.

Differential conductance measurements on Na_2SO_4 – $MgCl_2$ mixtures support the results obtained for $MgSO_4$ solutions. In these measurements, departures from additivity of equivalent conductances are a measure principally of $MgSO_4$ ion-pairing. Asymmetry in the curves is attributed to the smaller ion-pairing effects because of $MgCl^+$ and $NaSO_4^-$, the latter exhibiting about twice the pairing of the former.

Physiological Research Laboratory

The aim of the Physiological Research Laboratory (PRL) is to investigate the relationships between the life processes of marine and terrestrial organisms and their physical and chemical environment. Cooperative efforts in research and graduate studies between the members of PRL and the UC San Diego School of Medicine extend the capabilities of the laboratory. Research activities at PRL are currently oriented toward the physical nature of the gas nucleation process under high pressure; the retrieval, maintenance, and study of deep-sea organisms; cardiorespiratory physiology and energetics of marine mammals; lower vertebrates and invertebrates; comparative studies of acid-base regulation and gas transport; the biophysics of solutes in thermal gradients, and transduction of neural information.

The laboratory of Dr. A. Aristides Yayanos was engaged in deep-sea amphipod biology and microbiology. The methods for working with captive amphipods in pressure-retaining traps are being perfected to allow for more precise and accurate measurements of metabolism. Animals have been recovered alive with these traps from depths of 3,800 m and 5,700 m. After the animals die, they begin to decompose because of autolytic and microbial processes.

These processes of decomposition offer an opportunity to study aspects of the nitrogen cycle under deep-sea conditions. Dr. Yayanos' group has isolated bacteria from a trap containing decomposing amphipods in pure cultures. The characterization of some of these bacteria has begun, and one strain has proved to be especially interesting. It is a bacterium that grows, in tests to date, only at high pressures above 100 atm and at temperatures less than 10°C.

Dr. Edvard A. Hemmingsen and graduate student Wayne A. Gerth continue studies on spontaneous nucleation of bubbles. They are examining the physical mechanism that underlies the nucleation process and the factors that affect it. This study is part of a multi-year research program dealing with some aspects of bubble formation in organisms, as in bends. Fundamental information as to where and how the bubbles form, and the conditions that promote their formation, is largely lacking. Valuable information can be obtained to resolve some of these problems by comparing the nucleation properties of *in vitro* model systems with those of various cells. Light may be shed on the state of intracellular water and on the gas secretion mechanism in deep-sea fishes. In conjunction with the preceding studies, Dr. Hemmingsen and Gerth determined the solubilities of argon and nitrogen in various aqueous solutions at gas pressures up to 300 atm.

UC San Diego School of Medicine graduate student Randall E. Kaul and Dr. Harold T. Hammel, in collaboration with colleagues at the Max Planck Institute for Physiological and Clinical Research, West Germany, are investigating the properties of the body fluids that determine the rate of salt gland secretion in the Peking duck. When a sodium chloride solution equivalent to seawater is intravenously infused, the salt is secreted at about the same rate and concentration by the nasal salt glands. A small increase in the osmolality of the body fluids of 1 to 3 mosm/kg H_2O may cause an increase in the rate of secretion from 0 to near maximum. However, this change alone is not sufficient to account for the secretion of salt, since the plasma osmolality may be caused to vary 15 to 20 mosm/Kg H_2O either by dehydration or by retention of water; still the amount and rate of secretion will equal the amount and rate of infusion of salt. It appears that the threshold plasma osmolality varies inversely with the interstitial volume or some correlate of this volume.

Investigations of respiratory adaptations in aquatic vertebrates continue to be the major thrust of Dr. Gerald L. Kooyman's research. This research concerns the behavior, physiology, and anatomy of those aquatic vertebrates that swim at high speeds and those that dive to great depths.

To better understand the physiological adjustment that makes it possible for seals and sea lions to dive deeply; they are being dived under controlled conditions. During this time the effects of compression are being quantified by measuring the lung volume and the amount of lung collapse that occurs because of the compression.

Complementary to these investigations is a study of Weddell seals. While the seal voluntarily dives under the sea ice at McMurdo Sound, Antarctica, a time-depth recorder plots a profile of every dive. At the end of the dive blood samples are collected and analyzed. Certain changes in the blood chemistry before and after dives yield information about the physiological adjustments during the dive.

PHYSIOLOGICAL RESEARCH LABORATORY

A sea otter accepts a handout from Dan Costa.

An investigation of the energy production of sea otters and the effects of oil contamination of the fur, such as might occur during an oil spill, is under way. An analysis of oil-decontaminating materials and the procedures of their utilization is being assessed.

Drs. Fred N. White and Ralph A. Ackerman have determined that some aquatic turtles exhibit cyclical release of carbon dioxide. While diving or during protracted voluntary breath holding, CO_2 enters the lung at a very slow rate compared to oxygen depletion. This results in considerable decrease in lung volume; a fact that had previously been attributed to transcutaneous CO_2 loss. However, it was demonstrated that the "missing" CO_2 is recoverable in expired gas when ventilation is resumed. The explanation for such cyclical release of CO_2 is based on the rerouting of a fraction of the venous blood past the lung and an increase in the avidity with which the blood binds CO_2 during breath holding. Reversal of these trends during breathing causes pulsing of CO_2 as fresh air enters the lungs. Sequestration of CO_2 from the lung gas aids in the ability of hemoglobin to combine with oxygen and deplete the O_2 stores to very low levels during diving. Identification of a critical, low, lung oxygen level in the lung gas at which anaerobic metabolism commences allowed predictions of maximum aerobic submergence time. Observations of maximum voluntary diving time in the laboratory confirmed the predictions, and demonstrated that routine diving activity is terminated when accessible O_2 stores are depleted. This observation is contrary to the general view that anaerobic processes largely support metabolism during diving. It appears that the switch to anaerobic metabolism, with its consequent production of lactic acid, is reserved for "emergency" dives of longer duration.

Dr. H.-R. Duncker conducted anatomical investigations on the structure and morphometry of gas exchange organs of reptiles, marine mammals, and fishes. His observation that the muscles that produce water flow across the gills of sharks also attach to the membraneous sac surrounding the heart (pericardium), makes it probable that these muscles influence heart function and gill blood flow. During inspiration the muscles may lower pericardial pressure and allow more blood to flow into the heart. Increasing blood flow from heart to gills in this manner may provide more efficient matching of blood and water flows, and thus augment gas exchange.

Drs. Ackermann and White, in a cooperative study with Dr. Roger G. Spragg, UC San Diego School of Medicine, have examined the distribution of gases within the lungs of aquatic and terrestrial reptiles. Use of computer assisted imaging of radioactive xenon gas within the lungs allows the researchers to follow the distribution of gas during air breathing or prolonged breath holding. The effect of physical activity and contraction of smooth muscle in the wall of the lung has been quantified. The studies help to explain how the problem of gas stratification is overcome and gases are more effectively redistributed to the gas exchange surfaces of the lung during submergence.

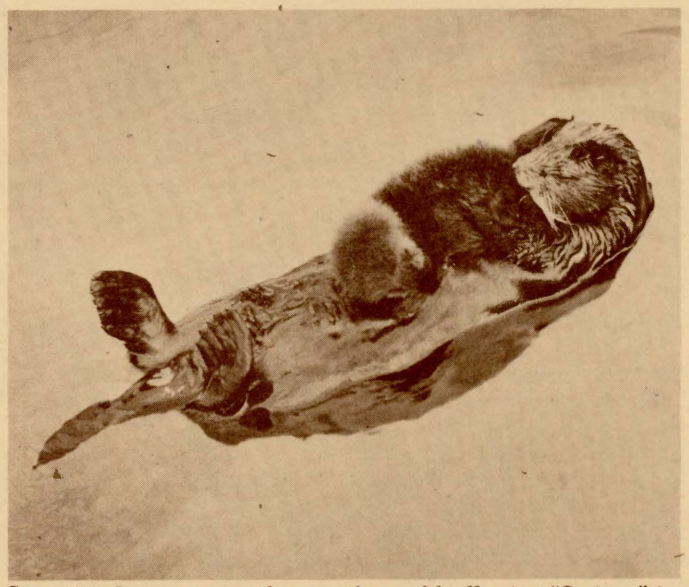
Dr. Hammel and James E. Maggert continue to develop the vapor-gap method for separating freshwater from seawater, in which seawater flows over a heated vertical surface where it partially vaporizes. The vapor diffuses across a gap, where it condenses on a cooled surface, and drains off the lower edge of the vertical cooled surface. The heated and cooled surfaces may be separated by less than 0.1 mm, so that heat of vaporization is rapidly transferred to the cooled surface. By alternating heated with cooled surfaces, a stack with sufficient surface area may be designed to transfer heat discharged from a power generating plant to the environment with potable water as a useful by-product. A patent is pending for this vapor-gap method.

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 observation associated with scientific investigations. 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.

Scientists at the laboratory have continued studies of the application of satellite remote sensing. The impending launch of the Coastal Zone Color Scanner on the Nimbus G satellite will provide the first opportunity for synoptic study of the ocean color in four spectral bands. Since the ocean color is primarily caused by plant pigments, chlorophyll, and associated degradation products, it is expected that the phytoplankton concentration in the surface waters of the world's oceans can be assessed from analysis of the Coastal Zone Color Scanner data. Roswell W. Austin and Drs. Raymond C. Smith and Wayne H. Wilson have been developing analytic techniques for estimating plant pigmentation from the remotely sensed data. The techniques include methods for removing the effects of the atmosphere from the satellite data.

Drs. Wilson and Dale A. Kiefer completed studies of the

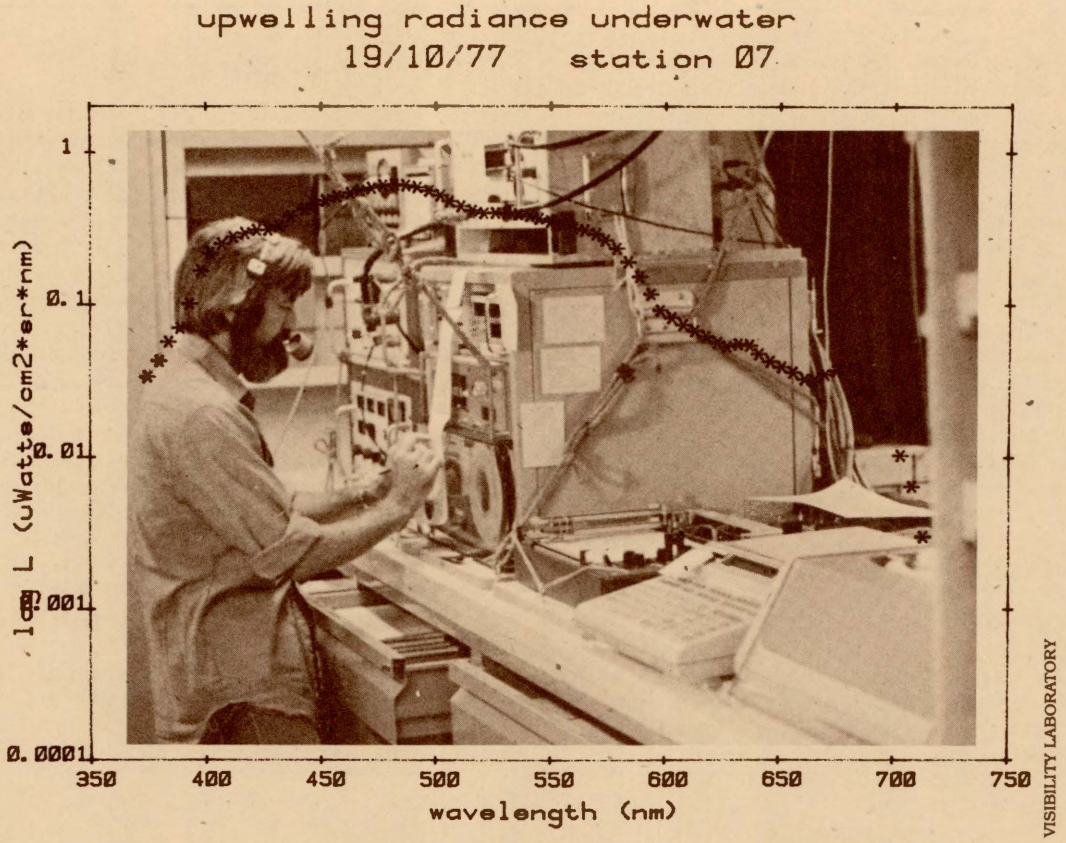


Sea otter Jenny grooms her two-hour-old offspring "Scripps" in the Physiological Research Laboratory's experimental pool.

reflectance spectrum of marine phytoplankton. Laboratory measurements were made of the scattering and absorption properties of cultures for various concentrations and growth rates. From these measurements, calculations of reflectance spectra were made.

Dr. Smith and Karen S. Baker studied the relationship between the vertical distribution of chlorophyll and the diffuse attenuation coefficient. Their analysis involved decomposing the spectral diffuse attentuation coefficient into separate contributions caused by the water, the chlorophyll and materials that covary with it, the yellow substance, and other non-covarying materials. By using these component spectral diffuse attenuation coefficients, the optical properties of any water may be determined by adding the appropriate amounts of each.

Dr. Smith and Baker also continued their research on the penetration of UV radiation into natural waters. Data were collected during a cruise of NOAA's R/V *Researcher* in the Gulf of Mexico. They measured UV-B penetration of



The Visibility Laboratory has been investigating methods of applying ocean color remote sensing techniques to the assessment of the biological productivity of the oceans. Dr. Raymond C. Smith is shown on a cruise working with equipment developed for the rapid acquisition and processing of in-water spectroradiometric data. In order to validate the methods developed, it is necessary to establish the physical and biological conditions that exist at surface test sites at the time the remotely sensed data are being obtained. Overlay is a computer printout of this data.

equatorial waters on a Pacific cruise from Kawajalein to Samoa, and also made productivity studies and chlorophyll measurements.

Gerald D. Edwards supported a program of the Naval Oceanographic Office, conducted off the coast of Spain, where he made depth profiles of scattering and absorption. He also participated in an experiment in which the National Aeronautics and Space Administration made Ocean Color Scanner overflights of Lake Erie, between the United States and Canada, and collected surface truth by measuring spectral radiance and irradiance. Theodore J. Petzold continued his studies of the optical properties of coastal waters.

James L. Harris, Sr., has initiated studies of the visibility of submerged objects. The studies involve analysis of the effects of the atmosphere, the air-sea interface, optical properties of the water, and the size, shape, and reflectance properties of the submerged object.

Harris continued studies on the mathematical modeling of human visual search performance. By defining properties of the objects to be sighted, the atmospheric and lighting conditions, and fundamental threshold data for the human visual system, the probability of detecting an object at any specified distance can be calculated. The studies are directed toward incorporating these concepts into a computer program that will make such calculations practical.

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

The aircraft and instruments form a sophisticated airborne platform in which a variety of optical and meteorological measurements can be continuously made and recorded.

Richard W. Johnson directed a European deployment in which aircraft and ground station data were collected in England and western Europe. He also directed the reduction and analysis of data acquired the previous year on a similar deployment.

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.

Benjamin L. 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. The computer simulation provides a means of evaluating the potential performance of postulated methods.

Deep Sea Drilling Project

Significant achievements in the field of technology as well as science marked the Deep Sea Drilling Project's progress during fiscal 1978. One record was attained when a 7,060-m drill string was suspended beneath the drilling vessel *Glomar Challenger*, while drilling in the Mariana Trench near Guam. The ship was working in water 7,044 m deep; that was also the deepest water column *Glomar Challenger* has ever drilled. Both accomplishments were recorded during Leg 60.

During Leg 55 of the Deep Sea Drilling Project (DSDP), which departed from Honolulu in July, scientists discovered that the Emperor Seamounts in the North Pacific Ocean once rose above the sea as tropical islands. The evidence, gathered during the 45-day scientific voyage, indi-

cates that 50 to 60 million years ago these huge, extinct, undersea volcanoes were once islands rimmed with coral reefs and sandy beaches, much like the Hawaiian Islands are today. The expedition scientists tested an important hypothesis about the origin of the Emperor Seamount chain and the history of motion of the crust of the Pacific Ocean during the past 70 million years.

The "hot-spot" hypothesis, first advanced in 1963, proposes that the Emperor Seamount chain is a continuation of the Hawaiian volcanic chain. Scientists on Leg 55 state that preliminary findings from four drilling sites on the Emperor Seamounts confirm this hypothesis.

Volcanic rocks were recovered from three of the holes drilled, and in the deepest hole at Suiko Seamount, the drill penetrated more than 70 lava flows. Shipboard examinations and chemical analyses show that the lavas of the Emperor Seamounts are indistinguishable from present-day Hawaiian lavas. Above the lava flows, scientists found black volcanic and white coral sand and fossils that lived only in shallow warm water, on coral reefs, near beaches, and in lagoons behind reefs. To test the idea that Suiko Seamount, now at 45°N, was born near 20°N, scientists measured the magnetism of the lava flows that record the direction of earth's magnetic field when they cool. From these magnetic directions, the position of the North Pole when the lava erupted can be determined. The results from the Suiko Seamount give a magnetic pole 20° different than that expected at the present latitude of the seamount and indicate that Suiko formed only 25° from the equator, as predicted. The ages of the fossils show that the Emperor volcanoes became progressively older from south to north as predicted by the hot-spot hypothesis. The fossils and coral sand show that as the volcanoes became extinct because of northward movement by the Pacific Plate away from the hot spot, their tops were eroded away by the sea, and coral reefs grew. Soon, however, the volcanoes sank beneath sea level and moved northward, and the coral reefs died, for above the coral sands are sediments that contain fossils that lived in water too deep and too cold for corals to grow.

Leg 56 was a 30-day expedition to obtain samples from below the deep ocean floor of the Japan Trench. Six holes were drilled at three locations: two on the steep landward wall of the trench and the third on a gentle rise seaward. The area under study lies off the northern coast of Honshū, where the deepest part of the trench is more than 7,000 m below the surface of the sea.

Earth scientists think that the floor of the Pacific Ocean is being thrust beneath the islands of Japan. The Japan Trench is formed where the ocean floor is warped down before sliding under the continental margin east of the island of Honshū. Its downward progress is marked by the deep earthquake zone below Japan and the Sea of Japan. A principal objective of Leg 56 was to investigate what happens to the deep-sea sediments on the continental side of the trench. If the Pacific Plate is moving under Japan, the sediments should be exposed to great forces just at the point where the crust encounters the edge of the continent. Scientists have suggested that the edge of the continent acts like a giant snowplow and scrapes ocean sediment off the sea floor and piles it up to form a new addition to the continental margin.

To test this hypothesis, scientists drilled 600 m into the steep continental slope of the trench in 6,000 m of water. The samples brought up were mainly broken fragments of partly consolidated deep-sea sediments. These geologically young sediments were found to have been subjected to powerful compressive forces. At one point, the drill penetrated the same layer of rock four times, indicating that the layers had been broken and different slabs of the same layer had been pushed one on top of the other. Thus, evidence was obtained that sediments on the Japanese side of the trench had, indeed, been subjected to great forces.

Scientists continuing the studies begun during Leg 56 discovered on the following cruise that the main Japanese island of Honshū is but a small part of a former land mass that once extended 300 km beyond the present Pacific shore of the island to an area now occupied by the Japan Trench.

The evidence of the ancient land mass comes from cores brought up during Leg 57 from more than one kilometer below the ocean floor. Material recovered in the cores include 25-million-year-old sand deposits containing perfectly preserved shells of shallow marine clams and snails that were laid down atop jumbled beds of boulders thought to have been deposited on land. The boulder beds, which are about 50 m thick, in turn, rest above remnants of an eroded formation that is possibly more than 80 million years old. The boulders consist of materials derived from the eroded older formation and from volcanic rocks. The volcanic rocks provide strong evidence for the existence of a former volcanic arc that was associated with the ancient land mass. The volcanic arc was probably much like the chain of volcanoes that today forms the backbone of Japan, an example of which is the world famous Mount Fuji. Shipboard scientists have named the now sunken land mass the Oyashio ancient land mass after the widely known Oyashio Current that flows over it.

New data about the geological evolution of the northern Philippine Sea were accumulated during Leg 58, which began in December in Yokohama, Japan. The data indicate that part of the northwestern Philippine Sea floor in the Daito ridge and basin region stood above sea level about 40 to 50 million years ago. Then, this region was located farther to the south in the equatorial zone. Additionally,

DEEP SEA DRILLING PROJECT

Roughnecks aboard D/V Glomar Challenger *add another section of drill pipe to the "string" being lowered to the sea floor.*

the Shikoku Basin, in the eastern portion of the Philippine Sea, underwent an episode of basin-wide volcanic activity about 15 million years ago.

Shipboard measurement of the magnetic characteristics of the ancient geomagnetic field imprinted or "fossilized" within the sediments recovered by Leg 58 drilling in the Daito Ridge region shows that the area has drifted northward from the equator to its present position of about 25°N over a period of 45 million years. This is a distance of approximately 2,400 km. These fossils also show characteristics that indicate the ocean waters over the Diato Ridge were, at one time, tropical and equatorial in nature. These two points are offered by scientists as evidence supporting the northward drift of the Daito ridge and basin region.

Leg 59 was spent largely in the Philippine Sea between Okinawa and Guam where scientists investigated the nature and geologic history of ancient, submerged volcanic ridges — called remnant- or back-arcs — and the adjoining inter-arc basins. Remnant-arcs are of particular interest because they are thought to play an important role in the origin and growth of continents and are considered to be the site of emplacement of much of the world's metal resources.

During Leg 60, a series of holes was drilled across the Mariana Trough (the back-arc basin), the active Mariana Arc, and progressively deeper into the Mariana Trench. As a result, there is now more evidence that something similar to sea-floor spreading has occurred in the Mariana Trough. The formerly active West Mariana Ridge was split from the Mariana Arc, and volcanism on the ridge ceased about ten million years ago. The basin that formed between the sundered arcs was the Mariana Trough. The presently active volcanoes of the Mariana Arc are new, having been formed since that time on the east side of the trough.

The trench drilling provided the major surprise of the cruise. Some models of the subduction process had proposed that pieces of the Pacific Ocean floor should have been faulted into the western side of the trench. As this material was added, the fore-arc region should have been enlarged and uplifted. Instead, scientists on Leg 60 found evidence for subsidence (sinking) of the fore-arc region near the trench, even though some rocks obtained in the deepest holes in the trench may have originally been part of the Pacific Plate. It now appears that subduction in the Mariana Trench is a smoother process than anyone had suspected, with little accretion of material from the Pacific Plate, and that blocks of the fore-arc region are downdropping into the trench and may themselves become subducted.

Scripps Institution of Oceanography manages the Deep Sea Drilling Project, which is funded by the National Science Foundation through a contract with the University of California. The university subcontracts with Global Marine Inc., (GMI), Houston, Texas, for drilling and coring using GMI's *Glomar Challenger*. Dr. Melvin N. A. Peterson is project manager and principal investigator, Frank C. MacTernan is deputy project manager and chief engineer, and Dr. David G. Moore is chief scientist.

Scientific advice for DSDP is furnished by panels from the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). JOIDES members include eight other U.S. universities and five foreign institutions.

Marine Life Research Group

The objectives of the Marine Life Research Group are based on understanding the California Current and its variability, and those regions that influence this current. One of the programs, known as the California Cooperative Oceanic Fisheries Investigations (CalCOFI), began in 1948 and continues as a cooperative research program with the state of California's Department of Fish and Game, U.S. National Marine Fisheries Service, California Academy of Sciences, and recently with the Mexican government through its Instituto Nacional de Pesca, Mexico City. During the year, the Mexican research vessel *Alejandro de Humboldt* has been an active participant in the CalCOFI program of data collection off California and Baja California.

The Marine Life Research Group conducts research in physical, chemical, and biological oceanography. In addition to the California Current studies, research is also under way on the physical and biological oceanography of the entire Pacific Ocean.

Dr. Edward Brinton and Margaret D. Knight are examining the life histories and population characteristics of euphausiid crustaceans, krill, that inhabit the eastern Pacific, particularly those of the California Current. Plankton collected during the "warm-water years" of 1957-1958 is being reexamined in detail for comparison with that of the preceding and following years of cooler ocean climate. While the overall distributions of the dominant species changed little during these years, the timing and intensity of their recruitment pulses varied significantly, generally being earlier in the warm periods. The fate of a wide-spread population of the southerly species *Nyctiphanes simplex*, which colonized waters off southern California during 1957-1959, has been followed as it slowly reverted to the subtropical zone.

Graduate student Tarsicio Antezana's doctoral thesis details extraordinary adaptations of euphausiids to the fertile Chile-Peru Current system in which oxygen concentrations beneath the mixed layer are so low as to approach the limits of measurability. He found that many species regu-

A sample of Euphausia eximia, *a species of krill, from the southern part of the California Current where it is an abundant source of food for marine animals. Enlarged male specimen is 27 mm long.*

larly migrate down into the oxygen-deficient layer for daytime residence, and the very abundant krill of the region, *Euphausia mucronata*, even engage in active feeding there, supplementing their near-surface nighttime diet of mixed phytoplankton and zooplankton.

Knight's investigation of larval development of the Euphausiacea of the California Current continues with a study of *Euphausia eximia* through the use of samples collected by the CalCOFI program and Krill Expedition and larvae hatched in the laboratory. The species is abundant in the southern portion of the California Current and in the region of the South Equatorial Current. Larvae of the northern Pacific population have been identified and the developmental stages determined, but preliminary results of a study of larvae from the southern Pacific range of the species suggest that there may be consistent differences in morphology between the two populations; this variation is being examined more closely.

Vertical distribution of the larval stages of *E. eximia* is being studied by using day and night samples taken through eight depth intervals during Krill Expedition within the northern and southern Pacific ranges of the species.

Joseph L. Reid and Arnold W. Mantyla have described a mid-depth circulation pattern in the North Pacific Ocean that is substantially different from previous concepts. The large-scale oxygen distribution within the upper 1,500 m of the North Pacific Ocean reveals an extra zone of low oxygen near 30°-40°N in the east that is not easily compatible with a simple, large-scale, subtropical anticyclonic flow at mid-depth. Further examination of the relative flow patterns suggests that the large subtropical gyre generally supposed to be present at the sea surface has a very strong return flow southward, just east of the Kuroshio, and that this flow turns eastward near 20°-25°N and extends eastward at least as far as 160°E. At greater depths, near 1,000 m, it continues eastward all across the Pacific. The area of high steric height within the anticyclonic gyre at this depth is thus shaped like the letter C, with two branches extending eastward from the western boundary. Each branch has an eastward flow on its north side and a westward flow on its south side. The highest dissolved oxygen values at mid-depth are found near the western boundary, derived from the South Pacific, and the two eastward flows carry the higher-oxygen waters eastward as two tongues, which leave an area of lower oxygen values near 30°-40°N in the east.

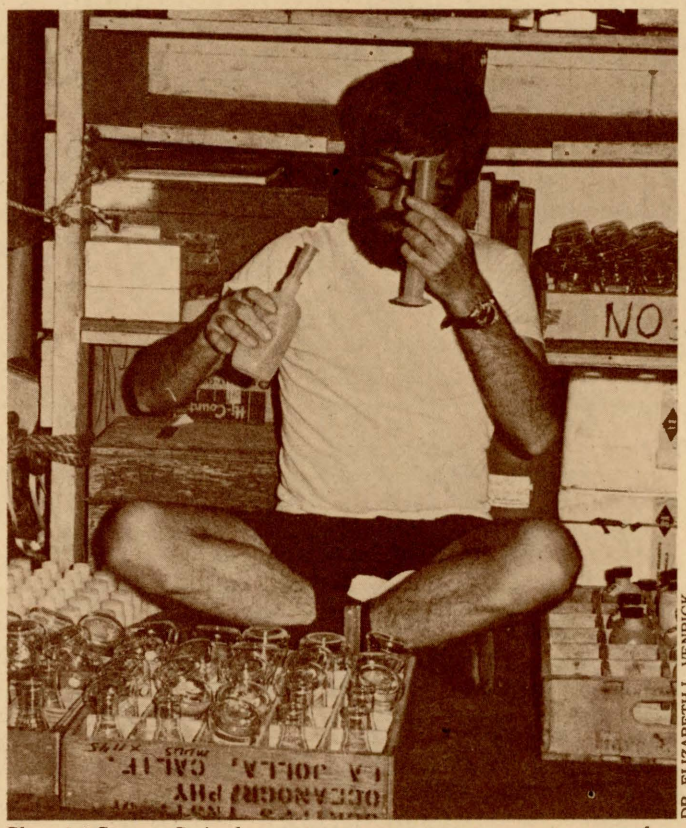
Reid made an analogous examination of the North Atlantic Ocean and found a similar result. The large-scale anticyclonic gyre generally supposed to be present within the upper waters of the North Atlantic Ocean is considerably altered at mid-depths. Not only is there a strong return flow westward just south and east of the Gulf Stream-North Atlantic Current, but this return flow also turns southward near 30°N and continues eastward all across the Atlantic. The warm and saline waters of the outflow from the Mediterranean Sea join the westward return flow south of the Gulf Stream-North Atlantic Current, and are carried westward as they spread and mix and form the great wedge of warm, saline waters found from 600 m to 2,600 m in the North Atlantic.

Dr. Abraham Fleminger studied planktonic copepods, taking into consideration the biogeographic and ecological qualities of spatial distribution, speciation, and adaptive morphological trends. This research continued his comparative studies on Atlantic and Pacific lineages. He focused his work on the Caribbean Sea region, where recent discoveries indicate the large omnivores that comprise the genus *Labidocera* underwent a speciation explosion apparently during the Pleistocene, and yielded unprecedented diversity for a planktonic taxon in relation to area. Of the eleven species of this near-surface-inhabiting genus found in the region, nine are coastal-water inhabitants endemic to the Caribbean region. For comparison, extensive systematic sampling in the larger eastern tropical Pacific region produced six tropical species, including three coastal-water inhabitants that are endemic.

A distinct correspondence between habitat preferences and phylogenetic affinities among congeneric species is a noteworthy feature of spatial distribution in Caribbean coastal-water copepods. This pattern is expressed by species of *Labidocera*, *Acartia*, and *Paracalanus*. Moreover, where habitats overlap, as indicated by co-occurrence of congeners in the same plankton sample, the species in contact belong to different phylogenetic groups. Relationships between habitat preferences and hydrographic conditions shown by Caribbean species of *Labidocera* and *Acartia* may help clarify puzzling distributional relationships among coastal-water species of *Labidocera* and *Acartia* in the California Current and the Gulf of California.

Dr. Elizabeth L. Venrick reports that in spite of the near universal application of systematic sampling designs, such designs violate the basic premise of random allocation of samples that underlies all statistical analysis and carries the risk of introducing bias into the results. In a two-part study of the planktonic environment, including computer simulation and field sampling, systematic sampling was compared with stratified random sampling in order to estimate the total amount of chlorophyll in the water column. The former design appeared to be more accurate than the latter, however, when repeated over restricted spatial or temporal intervals, systematic designs tended to produce biased estimates. In the central Pacific, a period of several days or 100-200 km appeared necessary to average out the bias inherent in the natural fluctuations of the population.

A comparison of the biological regimes of the eastern and western portions of the North Pacific Central Gyre, based



DR. ELIZABETH L. VENRICK

Chemist George C. Anderson is measuring out seawater samples for nutrient analysis.

mainly on data collected during the Indopac Expedition, was completed. Along latitude 35°N, in April 1976, five distinct environments were defined. The east central Pacific regime, closely related to the study site at 28°N 155°W, extended between the California Current and 160°W. The mesoscale heterogeneity of chlorophyll was significantly less than that west of 160°W, and mirrored the abrupt change in mesoscale eddy activity reported by physical oceanographers. This regime was significantly more oligotrophic than that of the other environments. It appears that the east central Pacific is not analogous to the Sargasso Sea and may have the most stable planktonic environment in the Northern Hemisphere.

The activities of the geobiological group fell into three study categories: biogeography, paleoclimatology, and environmental geochemistry.

The main effort in biogeography was Dr. Stanley A. Kling's participation in the Indopac Expedition to the North Pacific Central Gyre region in the summer and a cruise across the California Current in the fall of 1977. In both cruises an opening-closing fine-mesh net was used to collect radiolarians from the surface down to 2,000 m. Operation of the net was acoustically telemetered and controlled from the ship to provide precise depth positioning. Preliminary results from key stations established on these cruises indicate a subsurface radiolarian abundance maximum at the chlorophyll maximum.

A paleoclimatic study by Dr. Kling, Andrew Soutar, and Peter A. Crill was directed toward analysis of serial micropaleontologic data in relation to contemporary climatic parameters. It appears that two distinct temporal regimes can be defined in the California Current. Evidence points to current strength as the controlling parameter in the development of these regimes. Strong flow generally favors the development of subarctic forms and a high abundance of pelagic fish, while slack flow is associated with Pacific-wide El Niño conditions and favors the development of subtropical organisms.

A program in environmental geochemistry was directed by Soutar in which extensive surface sediment samples were collected in the Southern California Bight for analysis of hydrocarbons, trace metals, microbiology, and sedimentology. Cores were collected in the Santa Barbara, Santa Monica, San Pedro, and San Nicolas basins for detailed geochemical analysis, including age dating. These analyses were augmented by sediment data from traps sited directly above the core locations. This sampling system permits an incisive view of the natural and anthropogenic geochemical cycles in the southern California region. Preliminary results from standard chemistry and scanning electron microscope — X-ray spectrometry indicate that anthropogenic effects extend more widely than is generally supposed.

Dr. Charles S. Cox has continued his studies of energy diffusion in internal waves. Because internal waves interact with one another rapidly, the direct transmission of wave energy by radiation is interrupted after proceeding only a short distance. For longer distances one may describe the transmission as diffusive in character because the direction of motion of successive wave packets that carry the energy becomes randomized.

The distribution of electrical conductivity within rocks of the ocean crust and upper mantle is being evaluated by studies of the impedance of the earth to down-going electromagnetic disturbances in the water. Some of the disturbances are generated by water flow, and the identification of these processes is being interpreted in terms of the patterns of water flow. Electromagnetic data from the Atlantic Ocean have been used for these purposes, and some nonlinear effects of ocean waves have been identified in electromagnetic data in the Pacific.

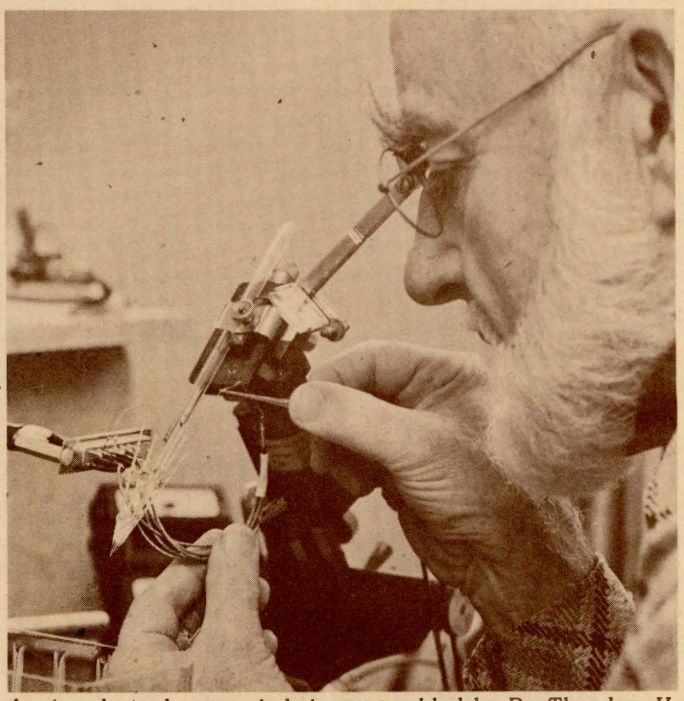
Dr. Lanna Cheng has studied marine insects, which have long been neglected by entomologists and by marine biologists, although several hundred species of insects either live in or are closely associated with marine environments. Most of the scattered information on these organisms has been recently brought together by Dr. Cheng.

During the Seaskater II Expedition around the Galápagos Islands, Dr. Cheng carried out research on the behavior and biological rhythms of *Halobates* and on the uptake of cadmium by *Halobates*, in collaboration with scientists from three other institutions. The insects tended to aggregate, and the aggregates remained in about the same position in relation to the surrounding environment irrespective of tidal movements; they also showed a bimodal daily activity rhythm. By using radioactive Cd-115m dissolved in seawater, Cd uptake by drinking was shown. The turnover rate is slow, and at least some of the metal taken up is stored in the insects' bodies.

Neurobiology Unit

The Neurobiology Unit is part of the Marine Biomedical Program that enlists scientists from the UC San Diego School of Medicine and Scripps Institution of Oceanography in projects of joint interest to marine biology and medicine. These range from octopus brain waves to the control of posture, but the main denominator of current activities is the processing of information from sense organs leading to behavior vital to the species.

Dr. Theodore H. Bullock studied the brain processing of input from electroreceptors in ten genera of siluriform fishes. This extends to nine the number of catfish families shown to have useful reception of feeble electric fields; thus the sensory system can now be regarded as general for this large group of fishes. Dr. Bullock and graduate student Jeffrey T. Corwin did the same in five genera of elasmobranchs; they characterized the responses to different frequencies and other parameters of the fields, and compared freshwater and salt-water reception. They also recorded the brain responses of sharks to acoustic stimuli, and confirmed physiologically that these animals can hear well, as behaviorists discovered several years ago. Corwin



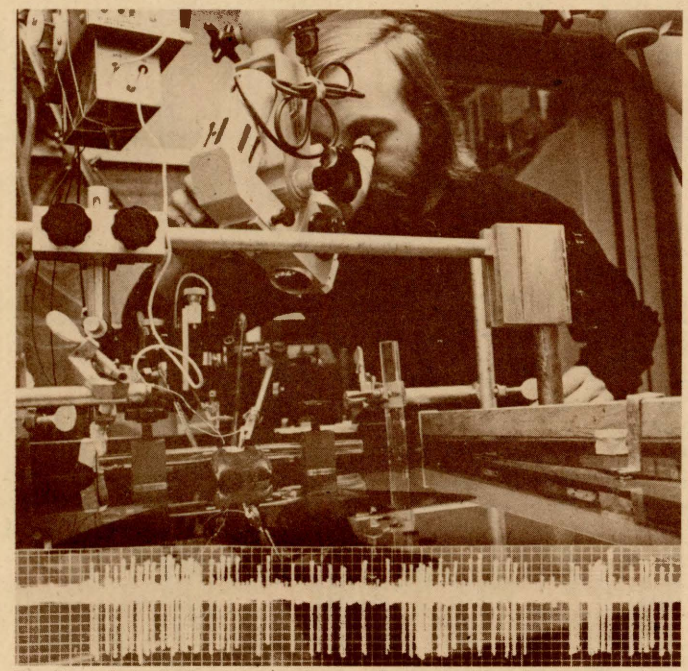
A microelectrode array is being assembled by Dr. Theodore H. Bullock for implantation into a shark brain.

examined the presumed sense organ with the scanning electron microscope and by radioautography. He also recorded from auditory nerve cells in the brain of a bony fish, and measured their behavioral responses to sound under computer control.

Dr. Bullock studied the ongoing electrical activity of the brain (brain waves) in various invertebrates and vertebrates. Drs. Bullock and Barry T. Davis found that sharks and rays are valuable models for studying seizures like those in epilepsy.

Dr. Terry A. Viancour analyzed the electroreceptors as frequency filters and especially the evidences for and factors contributing to their being tuned in each individual fish to match the normal stimulus. Visiting scientists Dr. Carl D. Hopkins, University of Minnesota, Minneapolis, and Dr. Joseph A. Bastian, University of Oklahoma, Norman, extended the study of single sensory and neural units, both in the skin and in the brain, in South American and African electric fish.

Dr. David A. Bodznick initiated experiments on the physiology of the sense of smell in sharks. He has recorded brain responses to odorous solutions injected into a continuous stream of seawater flushing the nose. This seawater included a few milliliters of water into which Dr. Bodznick had dipped his finger. Definite responses to the addition of the "treated water," were observed, while controls gave no such response. Dr. David W. Jensen completed a series of studies on the cooperation of receptors for head position with those for neck position in governing both posture and eye movements and on the role of different parts of the cerebellum in this integration. Dr. Jean K. Moore continued the anatomical study of stages in the evolution of the cochlear nuclei — the brain centers that are the first to receive and process auditory input from the ear. Dr. Robert C. Eaton completed work on the larval development of the identified command cell for startle responses in fish. Dr. William M. Saidel has taken up the visual system of cephalopods, continuing the study long pursued by Dr. G. David Lange. In particular he examined the nerve fibers that go from the brain to the eye. Jannon L. Fuchs is testing the señorita fish as material in which to study the basis of daily (approximately 24 hour) rhythms.



*Dr. David A. Bodznick implants electrode into the brain of an anesthetized horn shark (*Heterodontus francisci*) to record nerve cell responses to odors. Bottom of photograph shows printout of the response of a single brain cell to the odor of squid. Horizontal lines equal one second.*

Dr. Lisbeth Francis, Bates College, Lewiston, Maine, continued her studies of sea anemones that show aggressive behavior toward members of other clones. Thomas G. Uter designed several instruments, including a device that selectively cancels power line-related interference in high gain recordings; a device that records activity levels in fish by using low level infrared; a battery-powered, portable, stimulator for use in electrophysiology, and a stand-alone instrument for resistance measurement of filled glass microelectrodes.

Institute of Geophysics and Planetary Physics

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

Dr. Robert L. Parker continued work on a general statistical model for the magnetization of sea-floor basalts; he also compared predictions of the model with samples available from the Deep Sea Drilling Project. For some of the drill holes a good model is an entirely random distribution with very small vertical correlation length.

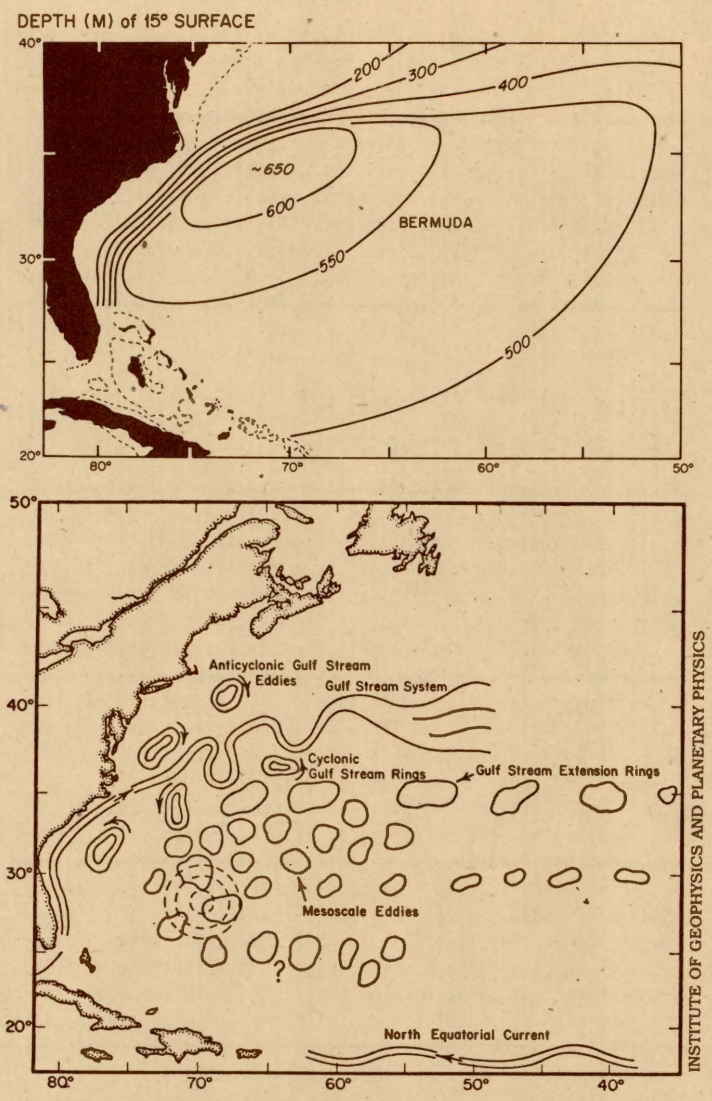
In theoretical solid-earth mechanics, Dr. George E. Backus has made progress on three problems: 1) Maxwell and Beltrami static stress potentials were shown to be members of a single class that could be given a coordinate-free description; 2) viability conditions for cavities in the deep mantle were worked out, and 3) stability conditions were obtained for plane shear flow in materials with a viscosity dependent on temperature and shear stress. In atmospheric electricity, an observational and theoretical case was made for the thesis that lightning superbolts result from electrostatic destabilization of the surface of the sea.

Spectral analysis techniques for obtaining high resolution estimates from short, noisy, data sets have been tested by Dr. Richard A. Haubrich over a broad set of computer generated examples. For data containing one or more narrow band signals, the all-pole or auto-regressive model is superior to Fourier techniques. Three methods of estimation for the all-pole model showed that bidirectional least square fitting was consistently better than the two alternatives using Burg or Yule-Walker covariance estimates.

Dr. Ralph H. Lovberg has made a detailed investigation of the temporal and spatial noise spectrum of CO_2 lasers. Such noise usually places a lower limit on the plasma fluctuation densities observable in this sort of experiment; any control that can be gained over the noise would represent a significant advance in the state of this technique.

In addition, he has developed the technique of apodization for small-angle scattering application (long known to astronomers), wherein noncircular optical apertures can substantially reduce diffraction noise in selected azimuths and thus allow resolution of very closely spaced objects. The application of apodization to scattering allows observations at smaller angles than have previously been accessible.

Drs. Walter H. Munk, Gordon O. Williams, and Peter F. Worcester and Bernard D. Zetler continued an ocean acoustics program in collaboration with scientists at Woods Hole Oceanographic Institution, Massachusetts, and the Massachusetts Institute of Technology, Cambridge. Experiments on the reciprocal transmission of acoustic signals between moored capsules are designed to correlate ocean processes with variability of sound trans-



The top figure illustrates the mean (climatological) subtropical gyre in the western North Atlantic. At any moment, it is composed of meanders, rings, and eddies (ocean weather), as shown schematically in the lower figure. The acoustic tomography experiments are designed to develop the capability of preparing ocean "weather" maps.

mission through the ocean's interior. A new procedure for monitoring ocean mesoscale perturbations appears possible. Ocean acoustic tomography would use an inverse calculation of anomalies in measured travel times between acoustic transmitters and receivers to provide a spacial distribution of changes in sound speed and, by inference, of changes in density. A long-range objective of the program is the development of a capability to routinely produce maps of the ocean comparable to conventional weather maps for the atmosphere.

In other aspects of physical oceanography, research continued on the dynamics of neutrally buoyant capsules and on methods of tide prediction. An intensive empirical comparison of response and harmonic tide predictions once more disclosed a statistical advantage to the former, as well as some special considerations for improving predictions by both methods for the particular tide stations under study.

Dr. C. Henry McComas numerically evaluated theoretical predictions of the third order spectra, which indicated nonlinear coupling among oceanic internal waves. He concluded that the predicted levels for the typical oceanic wave field were too low to be reliably observed.

Dr. John W. Miles continued his research on nonlinear waves, as governed by the Boussinesq and Korteweg-de Vries (KdV) equations. He solved the KdV equation for small nonlinearity/dispersion, and showed that an initial displacement of finite, non-negative volume, no matter how small, ultimately evolves into a solitary wave, as originally observed by Scott Russell. He also obtained an asymptotic solution to the KdV equation for initial conditions for which no solitary wave evolves. The latter solution led to an extensive study of the second Painlevé transcendent, which satisfies a nonlinear generalization of Airy's equation and has recently occurred in many nonlinear wave problems. He is currently working on generalizations of the Boussinesq and KdV equations for variable depth and two (horizontal) dimensions.

Dr. Wallace K. Melville and UC San Diego graduate student Peter Chang have continued experiments on the propagation of solitary waves in channels of slowly varying breadth b, finding that the theoretical approximation for the amplitude evolution ($a \propto b^{-2/3}$) is in agreement with the experiments for an increase of breadth, but not for a decrease of breadth. This discrepancy is being examined by numerical solution of the governing equations. A series of laboratory experiments on the reflection of a solitary wave at a wall has been completed and the data are being processed. Dr. Melville has also continued work on problems of air-sea interaction with laboratory experiments on the kinematics and dynamics of breaking waves.

Dr. Paola M. Rizzoli carried out numerical experiments that demonstrated the stability of solitary topographic Rossby waves. The persistence of these solutions over long times of integration reflects long-term correlations of various Fourier modes, correlations that are *a priori* denied in analytical turbulence theory.

Drs. Myrl C. Hendershott and Michael Parke formulated a model of ocean tides that both includes solid earth tides in a dynamically consistent manner and takes into account coastal and inland tidal observations.

Dr. Richard L. Salmon continued his theoretical study of highly nonlinear mid-ocean flow. He finds that large-scale currents may be either very barotropic (depth-independent) or very baroclinic, depending sensitively on the friction with the bottom.

Dr. Robert H. Stewart used HF radio waves in an experiment at Galveston Island, Texas, to measure wave growth caused by the wind as a function of angle relative to the wind, and the decay of waves caused by an opposing wind. He also continues to work with the National Aeronautics and Space Administration to evaluate the performance of Seasat-1, launched in June.

Dr. James N. Brune continued his seismic research project in Mexico, used physical models to understand earthquake strong motion, and analyzed new data pertaining to earthquake source mechanism. A new cooperative project with the Institute of Engineering, University of Mexico, Mexico City, to install an array of digitally telemetered seismic stations in northwestern Mexico was begun. With Dr. Gerald A. Frazier and graduate student Stephen H. Hartzell, studies were continued on the source mechanism of earthquakes, which focused on predicting earthquake strong motion for use in designing sensitive structures such as nuclear reactors. Field programs were begun to study earthquake source mechanism and spectra using new digital field recorders.

Dr. Hugh Bradner worked with offshore earthquake studies via sonobuoys, and continued his work 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 and graduate student Robert S. Howard continued studies of hyperbaric pulmonary physiology and decompression.

Graduate student Sally A. Look purifies organic solvents by distillation.

Sir Edward C. Bullard studied the disposal of nuclear waste and its relation to other parts of the fuel cycle. He also continued earlier investigations on the dynamo theory of the origin of the earth's magnetic field.

Dr. J. Freeman Gilbert's research, in collaboration with Drs. Jonathan Berger and Raymond P. Buland, has been devoted to studies of dissipation of energy radiated by earthquakes and procedures for the retrieval of earthquake source mechanisms from low-frequency spectra.

Dr. Berger continued the direction of Piñon Flat Geophysical Observatory, where the seismotectonics of southern California are studied and a long base-line tiltmeter is under development. A global network of very long-period seismic stations, Project IDA, has been under development and now consists of 13 stations, three within the United States and ten in foreign countries.

Three Cecil H. and Ida Green Scholars, Drs. Roger F. Dashen, Jackson R. Herring, and Christopher J. R. Garrett, did research on various problems including fluctuations in the propagation of sound in the ocean and the application of the methods of statistical turbulence theory to quasigeostropic flows.

Institute of Marine Resources

The Institute of Marine Resources (IMR) pursues research, education, and public service in the area of marine resources utilization. IMR provides a basis for studies to improve the nation's supply of organic and mineral materials, to harness the energies of the sea, and to extend the knowledge of ocean circulation, coastal wave climate and sediment transport, marine pollution, and waste disposal. The institute has facilities on the Davis and San Diego campuses of the University of California and is directed from Scripps by John D. Isaacs.

A brief account of the principal IMR activities at Scripps follows. A full description of this research is published in reports of IMR, Food Chain Research Group, and UC Sea Grant.

Scientists in the Food Chain Research Group (FCRG) study the ecology and trophodynamics of the organisms comprising the lower levels of the marine planktonic food webs. 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 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.

The principal investigators of the FCRG are Drs. Farooq Azam, John R. Beers, Angelo F. Carlucci, Richard W. Eppley, Osmund Holm-Hansen, Michael M. Mullin, and Peter M. Williams. Three of their major studies will be discussed here.

A sufficient understanding of plankton dynamics in the Southern California Bight is required to assess the effects of energy production and use on its shores on the resident marine populations. One aspect deals with the driving forces for overall plankton production. Stocks and production vary with the depth of nutrient-concentration gradients; they are high when the latter are near the surface during active and incipient upwelling periods, and low otherwise. They are also higher inshore than offshore, because of the shallowing of the gradients. Nitrogen as ammonia is released and recycled from decaying particulate matter, mainly bacteria and very small organisms. This activity parallels the photosynthetic and nitrate assimilation rates of the phytoplankton. A characteristic species assemblage of phytoplankton is found in the chlorophyll-maximum layer that differs from the surface assemblages. It seems to be dominated by dinoflagellates and other motile phytoplankton and by young life-stages of a carnivorous zooplankter of special trophic importance. Their lifetimes and spatial and temporal extent are under study.

In the Controlled Ecosystem Pollution Experiment (CEPEX), at Saanich Inlet, Vancouver Island, British Columbia, pollutants such as copper, mercury, and water-extracts of petroleum have been added to natural plankton in giant plastic bags. Bacteria and microzooplankters with their fast metabolism are principally responsible for the nutrient recycling and pollutant transformation. When bacterial populations were subjected to low levels of mercury, resistant forms were rapidly selected that could change ionic (toxic) mercury to metallic mercury and volatilize it, a possibly significant detoxification mechanism. The populations also become more resistant to other toxic materials, such as copper.

In December a hole was drilled through the 500-m-thick Ross Ice Shelf, Antarctica, into 200 m of free water. Population densities of bacteria were low, comparable to those of the deep sea, as were those of diatoms, dinoflagellates, tintinnids, other ciliates, and copepods. The sampled bacteria were metabolically active and capable of synthesizing RNA and DNA from tritium-labeled thymidine and uridine.

The central gyre of the North Pacific has been an area of intensive past investigations. In a revisit by scientists, the horizontal patchiness of plankton was studied in relation to the temperature distribution. No regular variability was found, as would occur if patches had characteristic dimensions, nor coherence between the temperature and chlorophyll records.

In these investigations it was found that the ^{14}C released in the nuclear weapon tests of the 1950s has entered the ocean as carbon dioxide. Of the part incorporated by the

plankton, some ^{14}C sank to deep water, some was respired as $^{14}CO_2$, and some was converted to dissolved organic matter. The dating made possible with this isotope has indicated the periods of some of these fluxes. In particulate matter/animal exchange it is a few years, while in dissolved organic matter it is in the order of thousands of years.

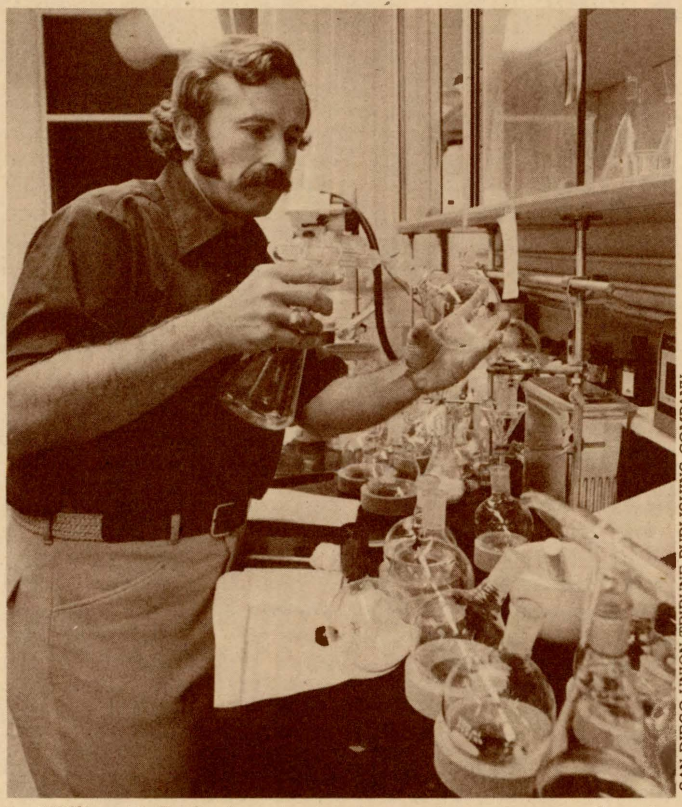
The University of California Sea Grant College Program, administered by IMR is headquartered at Scripps. Sea Grant fulfills its objectives of the wise utilization of the resources of the sea and the defense against the oceans hazards through support of many research and educational projects on California campuses.

From its initiation in 1966, the UC Sea Grant Program has become an extremely responsive mechanism for identifying and solving marine-related problems in California. It is integrated through its activiites — education, marine advisory services and research on coastal resources issues, aquaculture, fisheries, new marine products, and energy resources — to function as an efficient communication system for all Californians affected by the marine environment. Sea Grant represents a realistic solution to the onerous time lag between problem identification and solution. Sea Grant projects being conducted at Scripps are briefly described below.

An "Ocean Education for the Public" project under Donald W. Wilkie uses the Vaughan Aquarium-Museum staff and facilities to involve elementary and high school students in its group-education program.

Isaacs and Dr. Theodore H. Kerstetter, Humboldt State University, Arcata, California, initiated an evaluation of the marine resources of Humboldt and Del Norte counties. With local fishermen, Drs. Steven L. Costa and James W. Stork examined the possibility of introducing sophisticated sonar equipment to locate fish schools, the potential feasibility of exploring for submarine extensions of aquifers, and the need and possible solutions of greater utilization of Humboldt Bay, particularly through improvement of its hazardous entrance conditions.

The abalone, relished by gourmets and thus by commercial and sports fishermen, has received considerable attention in studies by Drs. Mia J. Tegner and Paul K. Dayton. Their frequent observations of juvenile abalones, under the canopies of red and purple sea urchins, have led them to an intensive examination of the preferred microhabitats of the young of this gastropod in the areas of the Channel Islands and Point Loma, California, where large abalone populations are currently thriving.



SAN DIEGO UNION-TRIBUNE PUBLISHING COMPANY

Dr. William H. Fenical separates chemical components of marine organisms by chromotography.

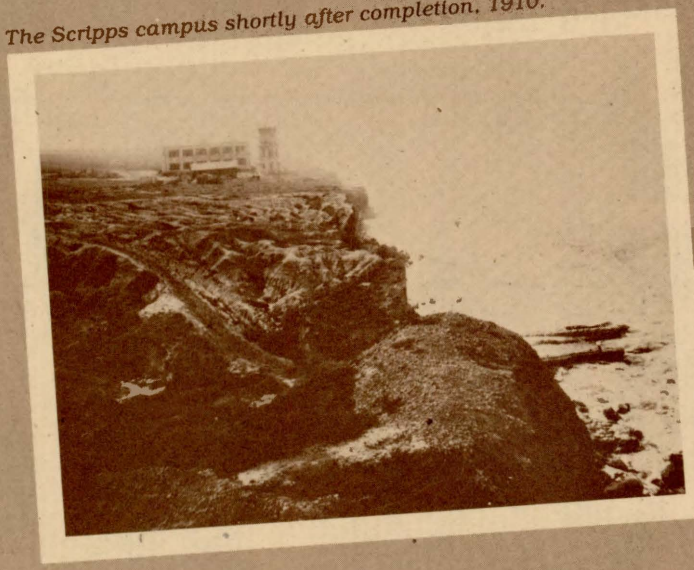
In pursuit of the parameters of distribution of marine thermophilic microorganisms, Francisco V. Vidal, Victor M. V. Vidal, and Isaacs have isolated strains from undersea hot springs and electric power plant condensers. The occurrence of the thermophiles in man-made systems interferes with system efficiency, and elucidation of their metabolic processes and growth responses may lead to future control methods. The investigators also hope to elaborate the mineralization processes known to occur where geothermal waters emerge in cold seawater.

Drs. Michael M. Mullin and Reuben Lasker studied the feeding habits of larvae of the jack mackerel, an abundant but underutilized Pacific fish. Laboratory observations of captured larvae, fed on captured wild zooplankton, will be compared with gut contents of larvae and nearby plankton collected by the CalCOFI sampling program. Results will serve as a basis for larvae-survival estimation in any given spawning season.

The quest for new marine products by California Sea Grant scientists proceeds at Scripps with two research projects. Dr. William H. Fenical studied chemical defense mechanisms of marine organisms, collected and extracted promising compounds, tested their effectiveness as herbicides or insecticides, and is now modifying the structures and synthesizing some of these compounds. The new variations will again be screened for effect as well as for environmental safety.

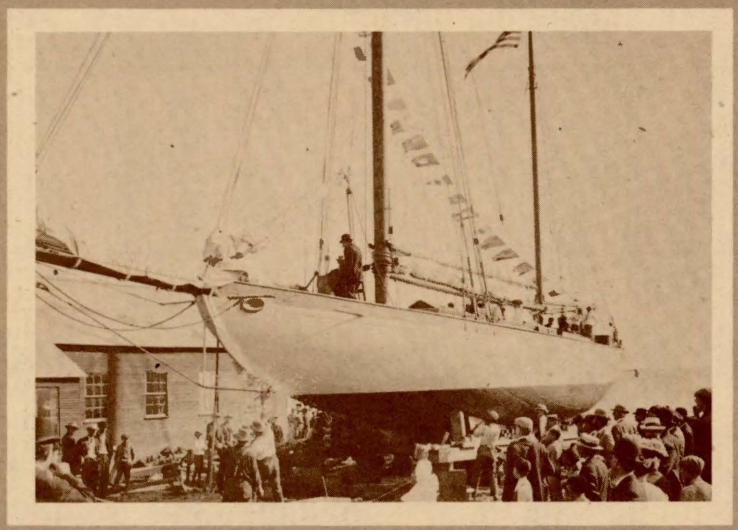
Similarly, Dr. D. John Faulkner has collected marine sponges from which he has extracted compounds for pharmaceutical evaluation. Both pure compounds and crude extracts are assayed for biological activity at UC Santa Barbara. Screening has already discerned antibiotic activity in 64 samples and anti-leukemic potential in several.

Scripps Through The Years



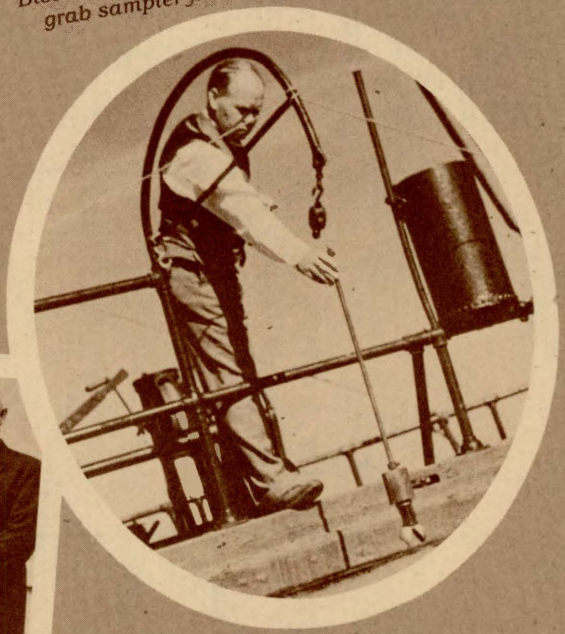
The Scripps campus shortly after completion, 1910.

Scripps Pier under construction, 1915-1916.



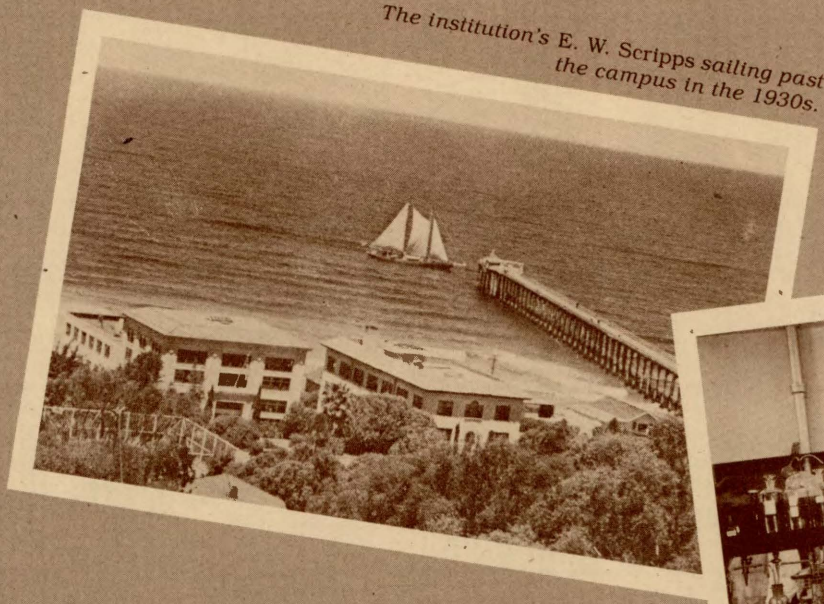
Christening of the first research ship owned by the institutton, Alexander Agassiz, tn 1907.

Biochemist Dr. Erik G. Moberg lowers a grab sampler from the Scripps Pier.

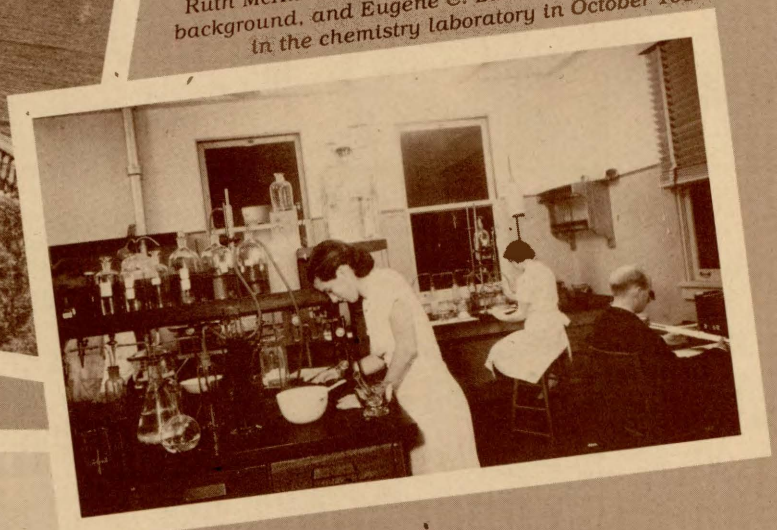


HISTORICAL COLLECTION
TITLE INSURANCE AND TRUST COMPANY
SAN DIEGO, CALIFORNIA

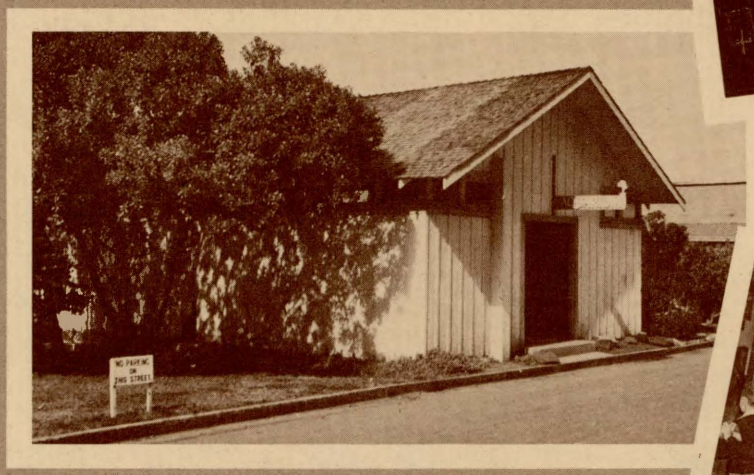
Dedication of the Scripps Institution for Biological Research on August 9, 1916. Left to right, William E. Ritter, D. T. MacDougal, David Starr Jordan, Bishop Joseph H. Johnson, G. H. Parker, and Benjamin Ide Wheeler.



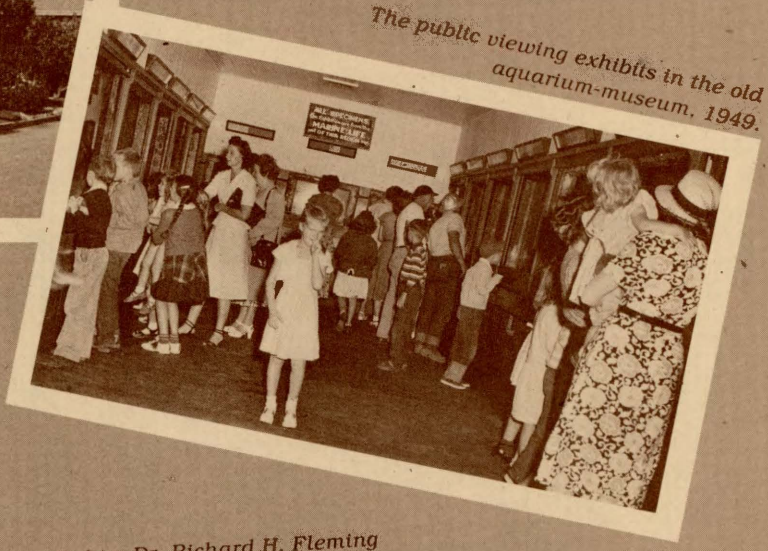
The institution's E. W. Scripps sailing past the campus in the 1930s.



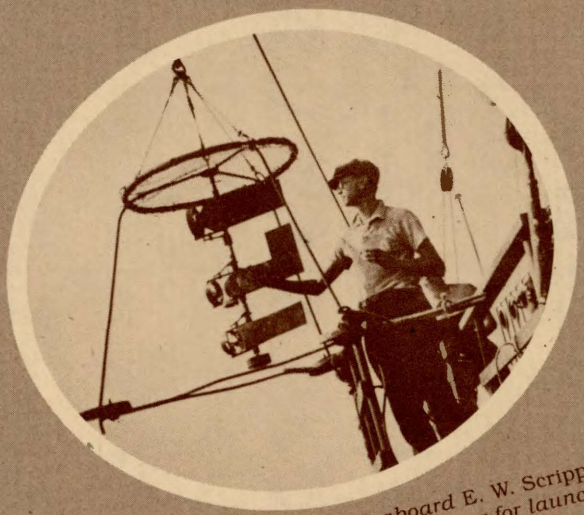
Ruth McKitrick at left, Katherine Gehring LaFond, background, and Eugene C. LaFond, right, at work in the chemistry laboratory in October 1933.



The first aquarium-museum building, built in 1915, as it appeared in 1949.



The public viewing exhibits in the old aquarium-museum, 1949.



Dr. Francis P. Shepard, aboard E. W. Scripps, prepares an Ekman current meter for launch, 1939.

Aboard ship, Dr. Richard H. Fleming hands Dr. Martin W. Johnson a Nansen bottle, 1935.

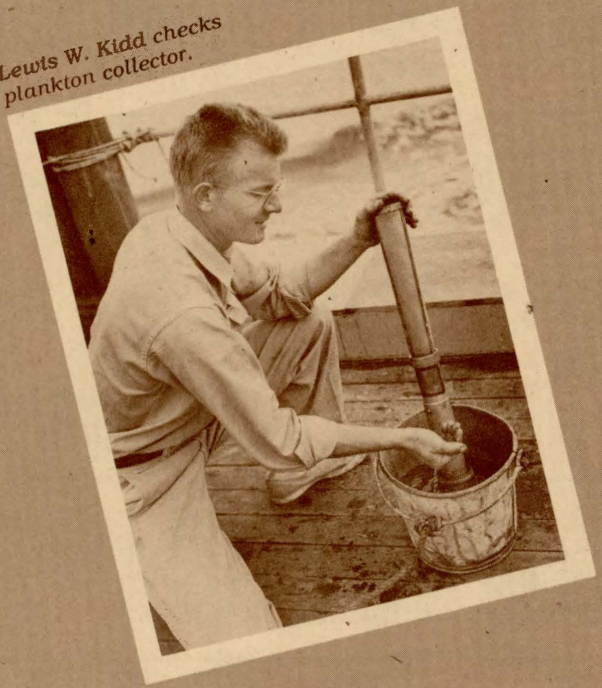
Dr. Carl L. Hubbs and Sam D. Hinton measure a salmon shark, 1950.

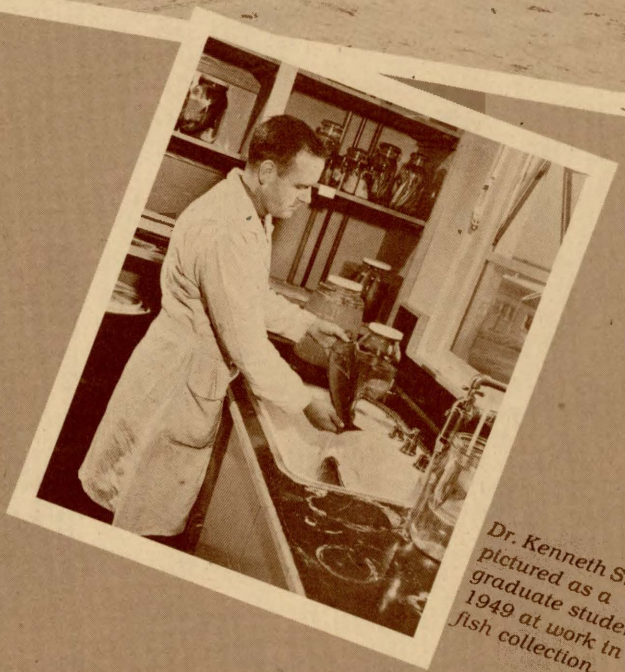
Three divers, left to right, Donald Saynor, Robert M. Norris, and David Poole, examine multi-sock sediment trap after retrieval.

The Scripps fleet in 1948, left to right, R/Vs Horizon, Paolina-I, and Crest.

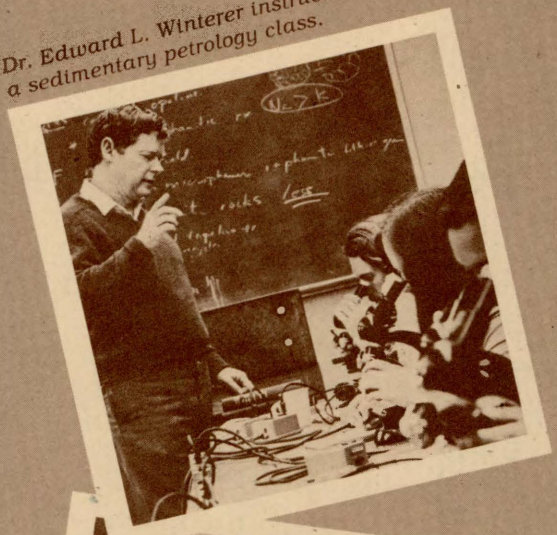
Professor and students seine for fish off the La Jolla shores.

Lewis W. Kidd checks plankton collector.

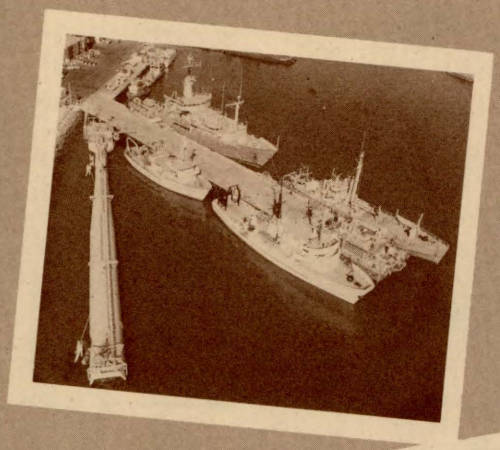




Dr. Kenneth S. Norris, pictured as a graduate student in 1949 at work in the fish collection.



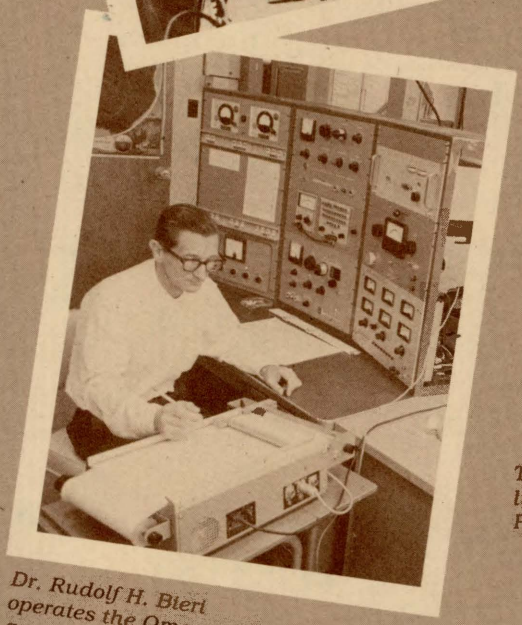
Dr. Edward L. Winterer instructs a sedimentary petrology class.



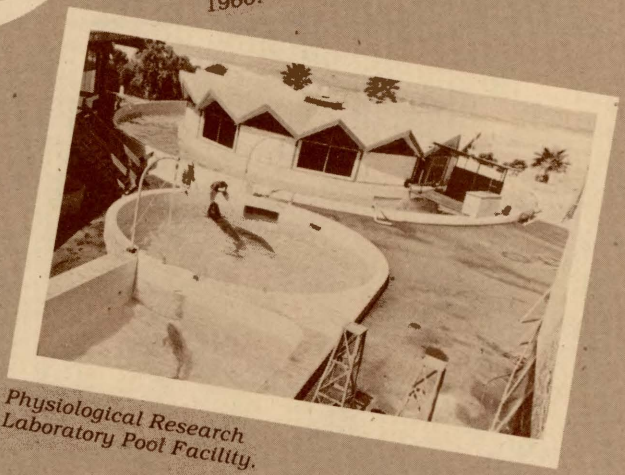
'Part of the Scripps fleet and National Marine Fisheries' David Starr Jordan, 1974.

Technician aboard R/V Argo in the Bering Sea during Zetes Expedition, 1966.

The late Dr. Edward W. Fager lifts a bongo net during the Piquero Expedition, 1969.

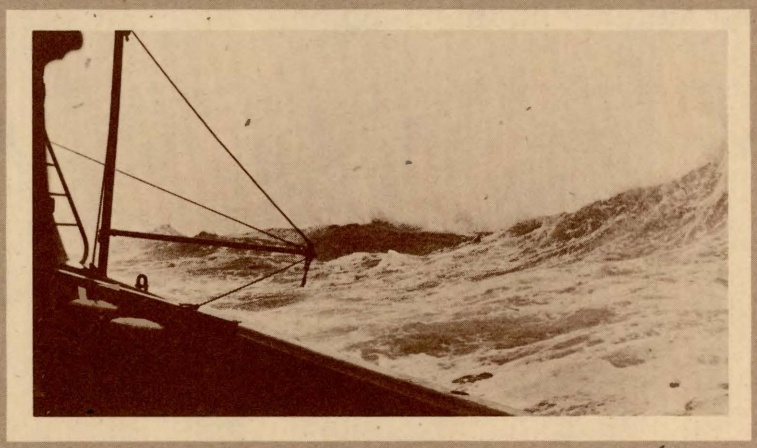


Dr. Rudolf H. Bieri operates the Omegatron, an analytical gas mass spectrometer.

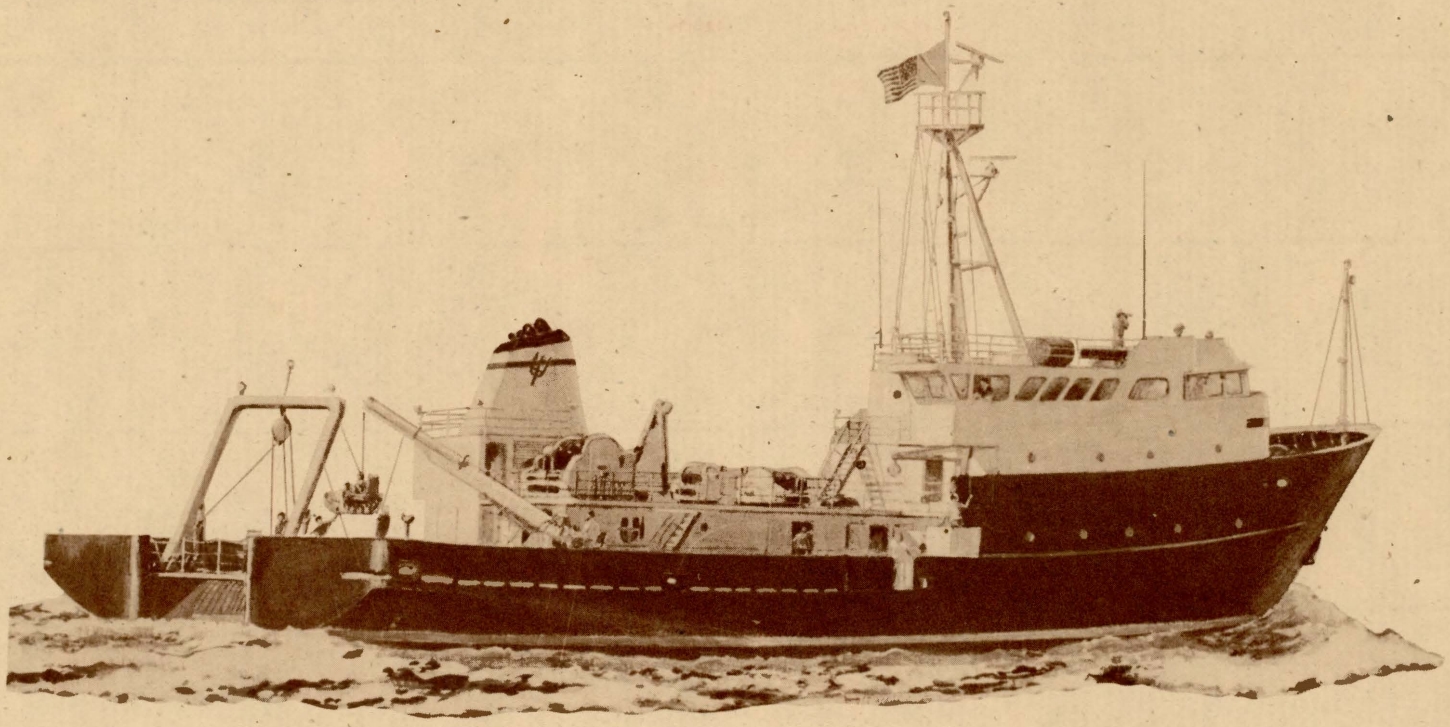


Physiological Research Laboratory Pool Facility.

Oceanographers wash down a meter net aboard a Scripps ship.



SEAGOING OPERATIONS



Artist's sketch of New Horizon, *a 52-m oceanographic vessel being built for Scripps. Funds to build the new ship were provided by the state of California, the first time the state has funded construction of a Scripps vessel.*

The Fleet

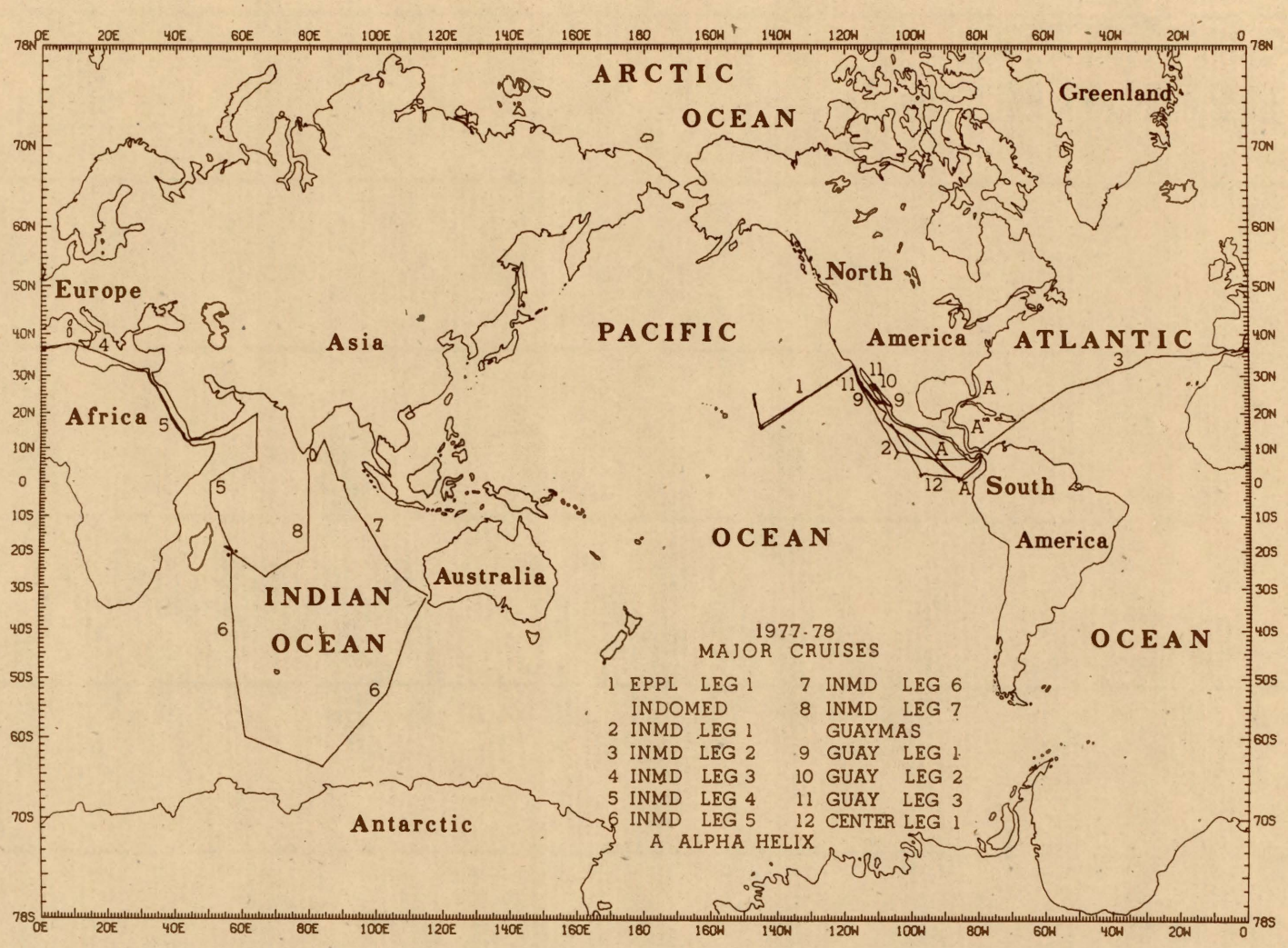
The year opened with all Scripps vessels operational. A contract to build a new mid-size oceanographic vessel with funds furnished by the state of California was given to the Atlantic Marine Shipbuilding Company, Jacksonville, Florida, and on October 7, 1977, the keel of *New Horizon* was laid. She was launched on April 4, 1978, with her completion date scheduled for the latter part of 1978. Scripps's four-ship fleet logged a total of 902 operating days and traveled 91,331 nautical miles.

R/V *Melville* was operating west of Central America, completing F DRAKE 77, as the fiscal year began. Dr. Kenneth C. Macdonald was the scientific leader of the geophysical leg, during which four ocean-bottom seismometers were recovered and surveys of the Middle America Trench and the Guadalupe Trough were conducted. Total mileage for F DRAKE 77 was 26,157 nautical miles, much of it far south in Drake Passage, near Antarctica. In July *Melville* was placed in a San Diego marine shipyard for her biennial overhaul.

In September *Melville* departed on Indomed Expedition, one that will keep her at sea for well over a year and a half. The first leg, from San Diego to Balboa, Canal Zone, was led by Dr. Fred N. Spiess, who conducted a deep-tow survey for the International Decade of Ocean Exploration (IDOE) Manganese Nodule Project. Instruments used included the deep-tow system, piston, box, boomerang, and gravity corers, with hydrocasts at selected areas. Dr. Wolfgang H. Berger was chief scientist for Leg 2, from Balboa to Cádiz, Spain. Box, gravity, and piston cores were taken across the North Atlantic Ocean in order to study the isotopic composition of fossils, the history of carbonate dissolution, and other properties of the Atlantic floor. From Cádiz through the Mediterranean Sea to Alexandria and then to Port Said, Egypt, *Melville* ran a primarily transit leg during which several geochemical samplings and tests were made.

The Geochemical Ocean Section Study (GEOSECS) then utilized *Melville* to sample Indian Ocean water in detail, as had been done in the Pacific and the Atlantic. Dr. Harmon Craig was the chief scientist from Port Said to Port Louis, Mauritius. Stations were selected to include as many major basins and sinks of deep water as time permitted; the hot brine pools deep in the Red Sea were objects of special attention. The southern traverse from Port Louis to Fremantle, Western Australia, on a track that skirted Antarctica, was supervised by Dr. Ray F. Weiss. On-board measurements, from 44-48 levels at each 30-hour station, included temperature, salinity, oxygen, phosphate, nitrate, silicate, nitrite, alkalinity, and total carbon. Dr. Wallace S. Broecker, Lamont-Doherty Geological Observatory, Palisades, New York, was chief scientist from Fremantle to Colombo, Sri Lanka, with a brief stop at Cocos-Keeling. Like the other legs of GEOSECS, this one included sampling seawater for particulates, carbon-14, tritium, rare gases, radon-222, radium-228, radium-226, silicon-32, lead-210, nickel, copper, cadmium, barium, and oxygen-18. Dr. Derek W. Spencer, Woods Hole Oceanographic Institution (WHOI), Massachusetts, led the fourth and final leg of GEOSECS, between Colombo and Port Louis by way of the Chagos-Laccadive Ridge.

After conversion of *Melville* from a geochemical to a geophysical-geological vessel at Port Louis, Indomed Expedition, under Dr. Robert L. Fisher, undertook a tectonic examination of the Southwest Indian Ridge far south of Madagascar and close to Marion-Crozet, before returning to Mauritius. Scientists employed magnetics, bathymetric and seismic-reflection profiling, as well as rock dredging,



to provide context for two long two-ship/sonobuoy seismic-refraction profiles of the Madagascar Ridge; the refraction profiling involved the French research vessel *Marion Dufresne* and her multi-channel seismic system. Leg 9 of Indomed during June, from Port Louis to Port Said, provided detailed deep-tow geophysical and geological observation of two areas straddling the spreading axis of the Red Sea. This investigation was led by Drs. Macdonald and Peter F. Lonsdale. Dredging and piston coring were used to complement the collection of igneous rock and metalliferous sediment samples. The year ended for *Melville* with a total of 288 days away from San Diego and a traverse of 40,966 nautical miles.

July 1, 1977, found R/V *Thomas Washington* in Honolulu being prepared for the sixteenth and final leg of her two-ocean Indopac Expedition. With chief scientists Drs. Michael M. Mullin and Kern E. Kenyon in charge, the vessel departed Honolulu. Biological investigations concerned the horizontal distribution of phytoplankton and zooplankton in differing environments. Samples were taken by pumping from near-surface waters during a long series of underway transects. Indopac, which began early in 1976, ended with *Thomas Washington*'s arrival in San Diego on July 31 and soon thereafter she underwent her biennial overhaul in Long Beach, California.

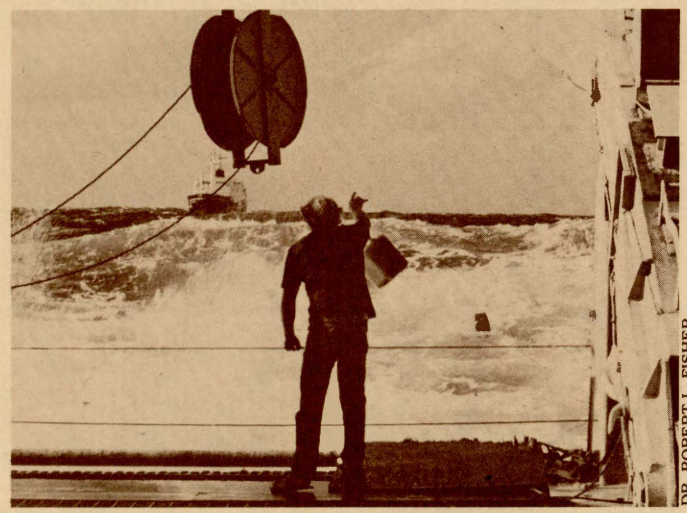
Early in October, with Dr. LeRoy M. Dorman as scientist in charge, *Thomas Washington* departed San Diego on cruise EPLL. This operation was designed to accomplish a long line seismic-refraction profile in the northeastern Pacific. The ship returned to San Diego in early November. Two local operations of one and two week duration followed, with Dr. Kenneth L. Smith directing *in situ* measurements of the benthic community. Early in February *Thomas Washington* departed San Diego with graduate student L. Dale Bibee as chief scientist to conduct rock dredging and a multi-channel seismic-reflection survey of proposed International Phase of Ocean Drilling (IPOD) drilling sites in the Gulf of California. After effecting ship generator repairs in Guaymas, Mexico, the vessel departed with Dr. Lawrence A. Lawver, U.S. Geological Survey, Menlo Park, California, in charge. A five-week reconnaissance of drilling sites was completed, a program that included not only reflection profiling, but also numerous gravity cores, heat probe lowerings, and hydrographic casts.

A local operation in collaboration with Oregon State University's R/V *Wecoma* involved scientists from two other institutions. Under the direction of Dr. Robert Spindel, WHOI, they set buoys and made underwater acoustic and physical oceanographic measurements. Then Dr. A. Aristides Yayanos, who has a long-term field program in hadal biology, used free vehicles for trapping isopods, made respirometer measurements, and practiced gravity coring and hydrocasts in the first of two short cruises in preparation for Mariana Expedition. In the late spring, Dr. Dorman again took *Thomas Washington* for a 35-day expedition in the coastal area, to deploy and recover ocean-bottom seismometers. *Thomas Washington* was employed for 186 days during the year and steamed 22,187 nautical miles.

Alpha Helix, operated by Scripps through the Alpha Helix Program and sponsored by the National Science

Foundation as a National Facility for field biological-biochemical-biomedical research, had been away for 16 months, principally up the Amazon River, when the year started. From then until her arrival in San Diego, she operated mainly under the direction of Scripps researchers. From year's beginning at Colón, Canal Zone, *Alpha Helix* proceeded north along the east coast of Central America, under the leadership of Dr. Abraham Fleminger. Scientists sampled zooplankton and marine mites from both ship and skiff. She then operated from Belize City, Belize, under the direction of Dr. D. John Faulkner, in a three-week scuba-diving investigation of algal and animal life, especially toxic sponges, on the coastal and offshore coralline reefs. This work concluded the Amazon-Caribbean Expedition, and *Alpha Helix* went into two months of biennial overhaul at Jacksonville, Florida.

By mid-October *Alpha Helix* was back in Belize City to undertake the Caribbean part of a long-term, multi-site study of sea grass ecosystems, largely in the Miskito Bank area off Nicaragua, under Dr. John C. Ogden, West Indies Laboratory, St. Croix. The vessel steamed to Colón and back to Belize City, while scientists conducted physiological experiments on the green turtle and made sediment collections and biomass analyses. From late November to late December *Alpha Helix* again steamed south to Colón on the second leg of Caribbean-Pacific Expedition, under Dr. Clement L. Markert, Yale University, New Haven, Connecticut, who directed investigations of the biochemical evolution of genes in fish; more than 123 species of western Caribbean coastal fish were examined. After a Christmas layover at Colón, Dr. Audrey Haschemeyer, Hunter College, City University of New York, and her colleagues continued the examination of fish, in this instance for studies of rates of protein synthesis in tissues from 20 species of living fish (of 50 species collected). Collection was initiated in the Caribbean off Panama, after *Alpha Helix* transited the canal, the protein metabolism program was continued off the Pearl Islands, Panama, and in the Galápagos Islands, Ecuador. Late in January at Academy Bay, Galápagos Islands, Dr. Lanna Cheng, chief scientist, studied the physiology and behavior of the water strider *Halobates* and the prochlorophytic alga *Prochloron*. *Alpha Helix* then returned to the mainland and passed into the Atlantic. During Leg 5 of Caribbean-Pacific Expedition, under Dr. Kenneth L. Rinehart, University of Illinois, Chicago, 545 species of marine life were examined for antibacterial, antifungal, and antiviral substances and for halogenative enzymes. *Alpha Helix* toured the Caribbean islands, cays, and reefs of Panama, Colombia, Nicaragua, Honduras, Belize, and Mexico. Finally, Dr. William A. Newman directed a coastal sampling traverse up the Pacific side of Central America, to collect and examine provincial and not-so-provincial barnacles, sponges, and decapod crustaceans. *Alpha Helix*'s Amazon-Caribbean-Eastern Equatorial Pacific odyssey ended at San Diego in April, after 26 months; in that time she had steamed 39,989 nautical miles.



DR. ROBERT L. FISHER

Ronald L. Comer heaves mail over the side of R/V Melville *to be retrieved and posted by French research vessel* Marion Dufresne. *Both ships were in the Indian Ocean, near the Madagascar Ridge.*

After a month of laboratory refurbishing in San Diego, *Alpha Helix* departed on the continuation of Caribbean-Pacific Expedition, for studies of natural products chemistry under Dr. William H. Fenical, at islands off Baja California, in the southern Gulf of California, and on the central Mexican coast. Year's end found *Alpha Helix* again in the Galápagos, with a program under Dr. George A. Bartholomew, UC Los Angeles, to investigate marine iguanas. In the preceding twelve months the vessel had operated for 277 days and steamed 18,588 nautical miles.

Ellen B. Scripps, Scripps's smallest seagoing vessel, made 44 sorties, ranging from 1 to 13 days at sea. Programs covered all disciplines, but usage was particularly heavy for bottom-seismometer geophysics, reflection profiling, research near outfalls, and marine mammal observations. Shorter trips emphasized student training and research, as well as equipment development and deployment. Most of the scientists were Scripps staff and students, but heavy users came from two other UC campuses: Santa Barbara and Santa Cruz. In operations ranging from Guadalupe Island, Mexico, to Monterey Bay, California, *Ellen B. Scripps* logged 151 days at sea and steamed 9,590 nautical miles.

Research platforms FLIP and ORB were used to conduct several operations in waters west of San Diego in programs of the Marine Physical Laboratory. Moored in 4,210 m of water, a 532-m vertical array of hydrophones was deployed from FLIP for Dr. Gerald B. Morris, Naval Oceanographic Research and Development Activity, Bay St. Louis, Mississippi, who conducted studies of the vertical distribution of ambient noise in the ocean. While FLIP was drifting prior to being moored, and after unmooring, Dr. G. Thomas Kaye used the installed 87.5 kHz Doppler sonar to investigate the characteristics of biological sound scatterers in the upper layers of the ocean. FLIP was towed 660 nautical miles during this 16-day sea trip.

ORB made five trips during the year, mooring consecutively in 1,010, 1,830, and 3,660 m of water, with the submersible acoustic array ADA tethered to one leg of the mooring. Dr. Victor C. Anderson conducted investigations of the noise statistics of the ocean, of propagation of various signals, and of the performance of the narrow-beam array at several depths to 810 m. ORB was towed 700 nautical miles during these tests, for a total of 58 days at sea.

Visiting Vessels

Nimitz Marine Facility occasionally provides berthing and logistic assistance to oceanographic research vessels from sister institutions or from other countries while engaged in collaborative research. *Alejandro de Humboldt* of Mexico's Instituto Nacional de Pesca has been supported quite extensively since late 1977; this ship has been carrying out the station pattern off Baja California for the CalCOFI California Cooperative Oceanic Fisheries Investigations program. Another Mexican vessel, *Mariano Matamoros*, berthed at Nimitz briefly, as did the French research vessel *Le Noroit*. Vessels from other institutions included *Velero IV* and *Sea Watch* of the University of Southern California and *Vantuna* of Occidental College, Los Angeles, California.

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 departmental requirements.

Progress is often most vigorous in the rapid development of modern marine sciences at the interdisciplinary level, so that the interests of a student, like those of the faculty, may overlap several curricular programs. It is the intent of the graduate department to provide flexibility in meeting the specific interests of the individual students.

Dr. Michael M. Mullin chaired the department during 1977-78. Dr. Myrl C. Hendershott, who served as vice-chairman of the department for the year, assumed the duties of acting chairman during Dr. Mullin's absence. The department includes 56 faculty members and 5 adjunct professors. In addition, 17 members of the professional research staff 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/Dr. Victor C. Anderson). 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 provide modern engineers with a substantial training in oceanography and oceanographers with a significant knowledge in modern engineering. Instruction and basic research include structural, mechanical, material, electrical, and physiological problems operating within the ocean and the applied science of the sea. Since physical, chemical, geological, and biological as-

Dr. Walter F. Heiligenberg demonstrates a set of micromanipulators to graduate students Joanne A. Matsubara, right, J. Harlen Meyer, second from right, and Dr. Brian L. Partridge, far left.

pects of the oceans and all disciplines of engineering may be involved, the curriculum provides flexibility in meeting the needs of each student.

Biological Oceanography (Dr. John A. McGowan/Dr. Paul K. Dayton). Biological oceanographers are concerned with the interactions of populations of marine organisms and with their physical-chemical environment. Research and instructional 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, statistical 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 train the physicist (theoretician or experimentalist) for the understanding of the sea, the solid earth on which the waters move, and the atmosphere with which the sea interacts. The program initially assists the student in assimilating basic knowledge concerning the nature of the earth and in mastering field, laboratory, and mathematical techniques by which new information is being developed. With this background, the student is then expected to gain 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/Dr. Jeffrey L. Bada). 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. H. William Menard/Dr. Albert E.J. Engel). 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.

Physical Oceanography (Dr. Robert S. Arthur/Dr. Russ E. Davis). 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

In the fall of 1977, 45 new students were admitted to graduate study. Of these, 11 were in marine biology, 8 in geological sciences, 5 in marine chemistry, 6 in biological oceanography, 4 in geophysics, 4 in physical oceanography, and 7 in applied ocean sciences. Sixteen were California residents, 21 were from out of state, and 8 were from foreign countries. Enrollment at the beginning of the academic year was 194. Nine Master of Science degrees and 31 Doctor of Philosophy degrees were awarded by UC San Diego to students who completed advanced studies during the year. The names of degree recipients, the titles of doctoral dissertations, and the names and new positions of Ph.D.s are listed in Appendix E.

Sumner Auditorium (left) and Sverdrup Hall (right) serve as a backdrop for a class in the sun.

SHORE FACILITIES AND COLLECTIONS

The location of facilities and collections described in this section is indicated primarily by letters in parentheses; they correspond to letters in the legend for the accompanying campus map.

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 displays, and a variety of educational programs. Public information services are also provided through responses to written and verbal inquiries.

Governor Jerry Brown (center) gets a briefing about the tide pool from aquarium director Donald W. Wilkie during the governor's recent visit. Also with Governor Brown are (left to right) John D. Isaacs, Dr. Charles J. Merdinger, and Dr. James J. Sullivan.

The staff, assisted by approximately 60 volunteer docents, conducts a diverse educational program. This year more than 58,000 students in educational groups toured the aquarium-museum. Other offerings included year around workshops, mini-marine biology courses, "outreach" program, 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.

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.

Although admission to the aquarium-museum is free, voluntary contributions from many of the more than 370,000 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 publications to a variety of children's books and general-interest materials.

Analytical Facility (p) and (h). The facility provides the staff and graduate students with analytical instruments and assistance to aid in 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; 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, 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 tabletop Olivetti computer, and geological field equipment. The facility's newest instrument is a scanning transmission electron microscope (STEM) with microanalytical capabilities.

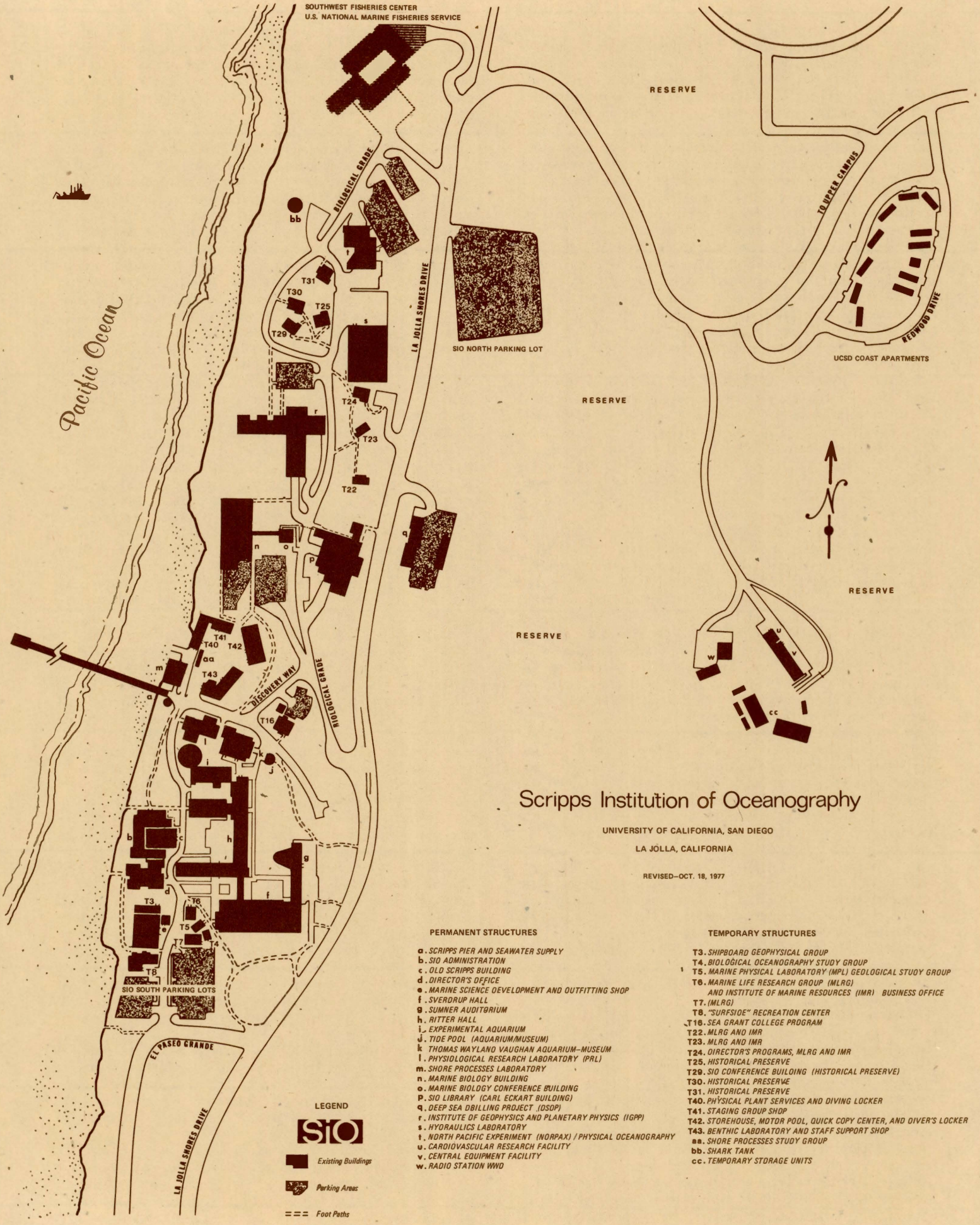
Cardiovascular Research Facility (u). Established in 1965 as a joint enterprise of Scripps's Physiological Research Laboratory and Scripps Clinic and Research Foundation, La Jolla, this facility consists of an experimental animal colony, equipment for physiological research involving measurements of 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 gear of the program; *i.e.*, air compressors, filters, air-storage bank, diver air-cylinder storage, and SCUBA regulator repair. The other contains a wet equipment storage locker and shower facilities.

Scripps's scientific diver-training program, the oldest of its type in the country, provides training for more than 80 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 underwater; however, federal, state, and local government employees may be admitted by special permission. There are currently 150 faculty, staff, and students who collectively make an average of 4,500 scientific dives per year. These dives take place 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.

Experimental Aquarium (i). Used by the faculty, research staff, and graduate students for various studies of living plants and animals, the experimental 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-



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. *OLD 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 (DSDP)*
- 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*

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; it is a 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.

Marine Science Development and Outfitting Shop (e). This shop is equipped with precision tools and machinery. A staff of toolmakers and diemakers designs, develops, and fabricates 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.

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 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 making use of both anthropogenic and natural radionuclides to study geochemical processes in both the marine and terrestrial environments.

Petrological Laboratory (h). This facility provides thin-sectioning, microprobe sample preparation, and rock-surfacing services to the staff and students 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. In addition, a fully equipped petrological laboratory is available for students and staff in which they may prepare their own thin sections.

Physiological Research Laboratory Pool Facility (e). 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 echolocation 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, 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, radioteletype, and facsimile transmissions can be handled by the station, which operates 12 hours a day Monday through Friday, and eight hours a day Saturday, Sunday, and holidays.

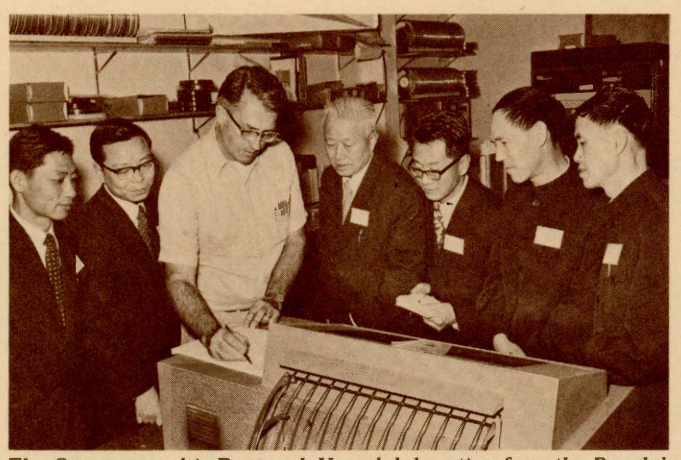
San Vicente Lake Calibration Facility (48 km from Scripps). This facility, operated by the Marine Physical Laboratory, is equipped for testing and calibrating acoustic transducers used in oceanographic research. The equipment is located on an 8x15-m enclosed platform in 40 m of water and offers 1,372 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, 1978, the library housed 120,969 bound volumes; 31,854 maps and charts; 20,611 reprints; 30,283 documents, reports, and translations; and 5,782 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 (w). 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, and an automatic gauge records tidal fluctuations. In addition, the pier serves as a boat launching site for small boats utilized to conduct oceanographic work in the local area.

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 sand filters and two concrete storage tanks having a total capacity of 439,060 *l*. Delivery capacity is 5,300 *l* per minute.

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



The Oceanographic Research Vessel delegation from the People's Republic of China looks on as Lynn Abbott, third from left, demonstrates Scripps's computers to Tai Li-jen, captain of an oceanographic research vessel.

Thomas Washington and R/V *Melville* and on campus in Ritter Hall and in the NORPAX/Physical Oceanography 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 ship's course and speed and to 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 Group (SCG), 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.

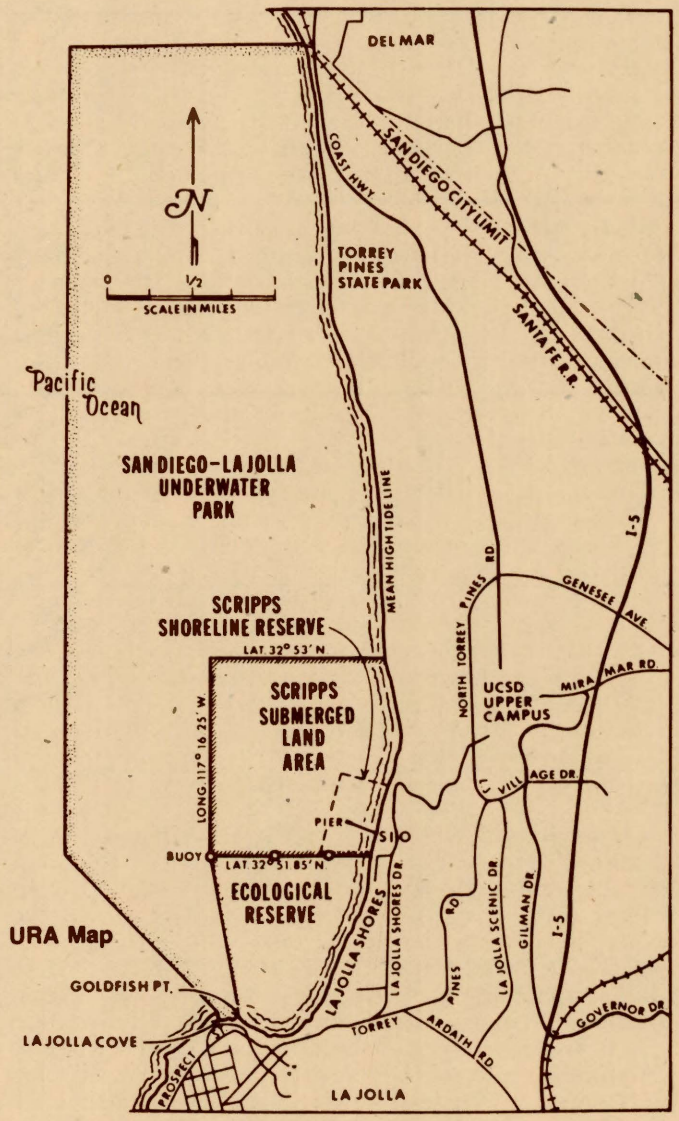
A Prime 500 computer system was installed in the Institute of Geophysics and Planetary Physics basement in May and is managed by SCG. The Prime 500 is well adapted to economical number-crunching with a 6.5 μs floating point (64 bits) multiplier, one megabyte of memory and 300 megabytes of disk. Its use is primarily by CRT terminals.

Shore Processes Laboratory (m). The laboratory conducts teaching and research investigations of physical and sedimentary processes in the nearshore environment. It is housed in 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 collection and processing is achieved with two Interdata Model 70 minicomputers and an Interdata Model 8/32, equipped with disk storage units, digital tape recorders, a paper tape recorder, graphic plotter, and CRT terminals. The building also houses an extensive library of reference material on coastal-zone processes and a collection of nearshore sediment samples.

Underwater Research Areas:

Scripps Shoreline Reserve (Underwater Reserve Area [URA] map). 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 (URA Map). The University of California leases from the city of San Diego approximately 640 acres 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 Scripps. This area is currently unmarked.



Underwater Research Area map

Ecological Reserve (URA Map). The 580-acre San Diego-La Jolla Ecological Reserve extends southward from the Scripps 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 Coelenterata, Echinodermata, and Mollusca. All are cataloged with collection data and more than 35 percent are identified according to species. The Decapod Crustacea (SIO Reference Series No. 77-9, 1977) and Brachiopoda (SIO Reference Series No. 78-19, 1978) are the first to be published in a new series of catalogs. 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 and by students. Effort is being made to inform potential researchers of the general nature of all available cores and dredge hauls.

Geological Data Center (h). Most of the geological/geophysical data collected by Scripps vessels while under way 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 more than 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 Botany Collection (n). A small herbarium of marine benthic algae comprises specimens collected from the San Diego area, and the Pacific coast of the United States, and during Scripps expeditions in the Pacific Ocean. The material is primarily used as a teaching tool.

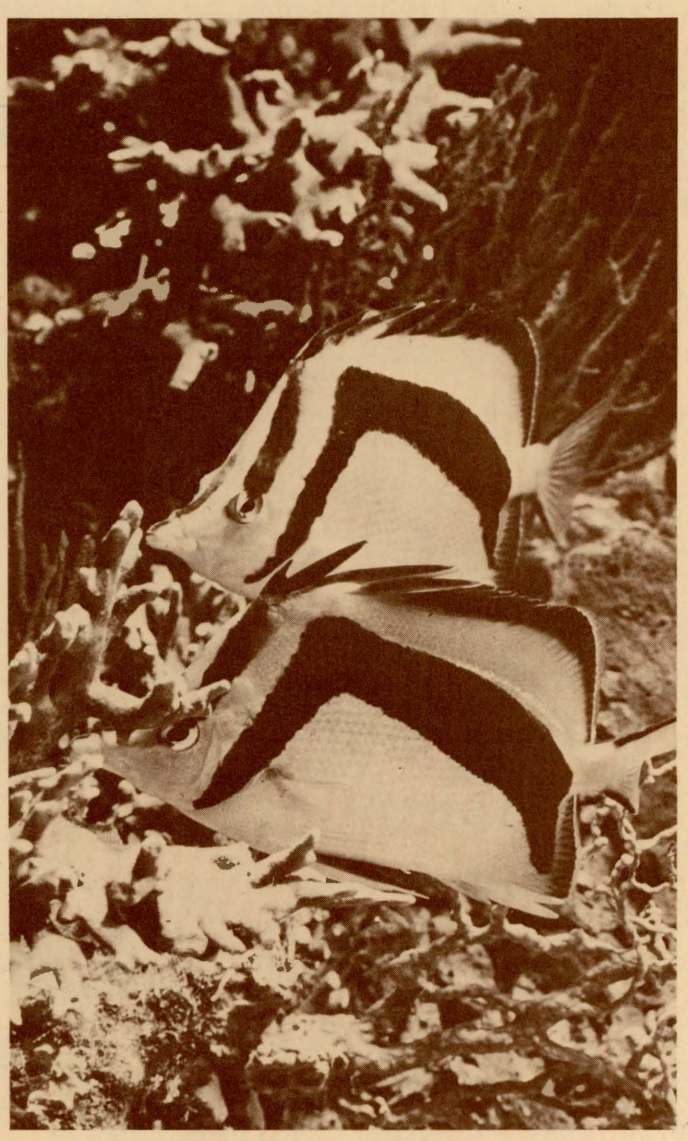
Marine Invertebrates (Zooplankton Collection, h and 6 km east of Scripps). In this collection are nearly 65,000 documented zooplankton samples; of these more than 21,600 are from special collections and expeditions and some 2,200 from mid-water trawls. Included are sorted specimens and identified collections 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). More than 3,100 cataloged species of marine fishes and approximately 2 million specimens are in this collection. Added in 1977 were 400 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.

Historical meteorological and oceanographic data for the Pacific are kept in the NORPAX data library. These data include marine weather and sea-surface temperature observations from 1854 to the present; National Oceanographic Data Center files to 1976; and monthly pressure, temperature, and precipitation at selected World Meteorological Organization stations around the world.



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 short data reports to long taxonomic descriptions. Scripps publications are distributed by subscription, exchange, or government contract.

Below is a complete listing of the Scripps Institution of Oceanography publications for fiscal 1978. Detailed availability information is included for each series.

Bulletin

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

Listed 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.

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The atlas issued this year is listed below.

No. 25 **Eber**, L. E. Contoured depth-time charts (0 to 200 m, 1950 to 1966) of temperature, salinity, oxygen, and sigma-t at 23 CalCOFI stations in the California Current. June 1977. 238p.

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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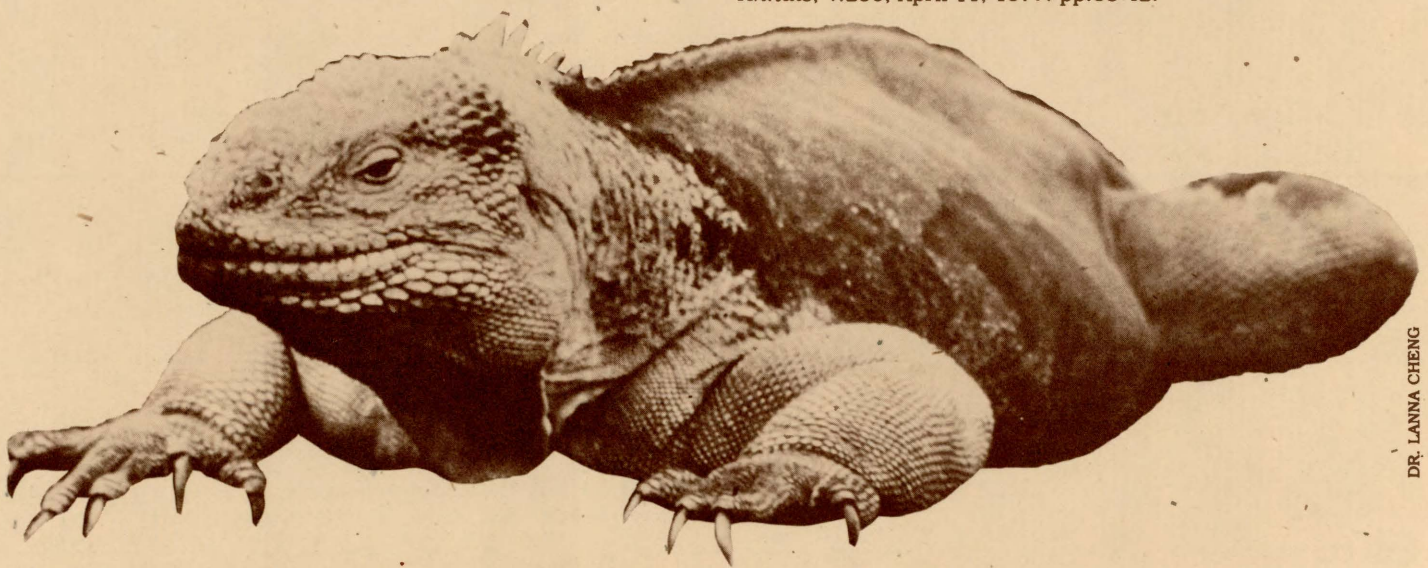
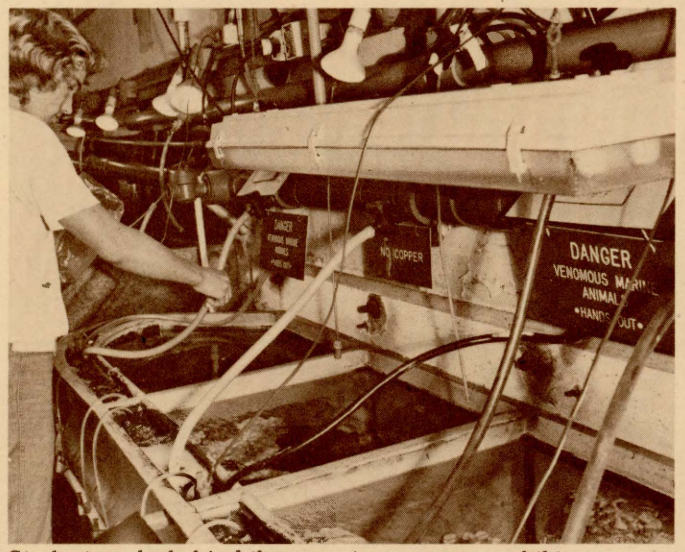


DR. LANNA CHENG

Land iguana photographed in the Galápagos Islands during a cruise of R/V Alpha Helix.



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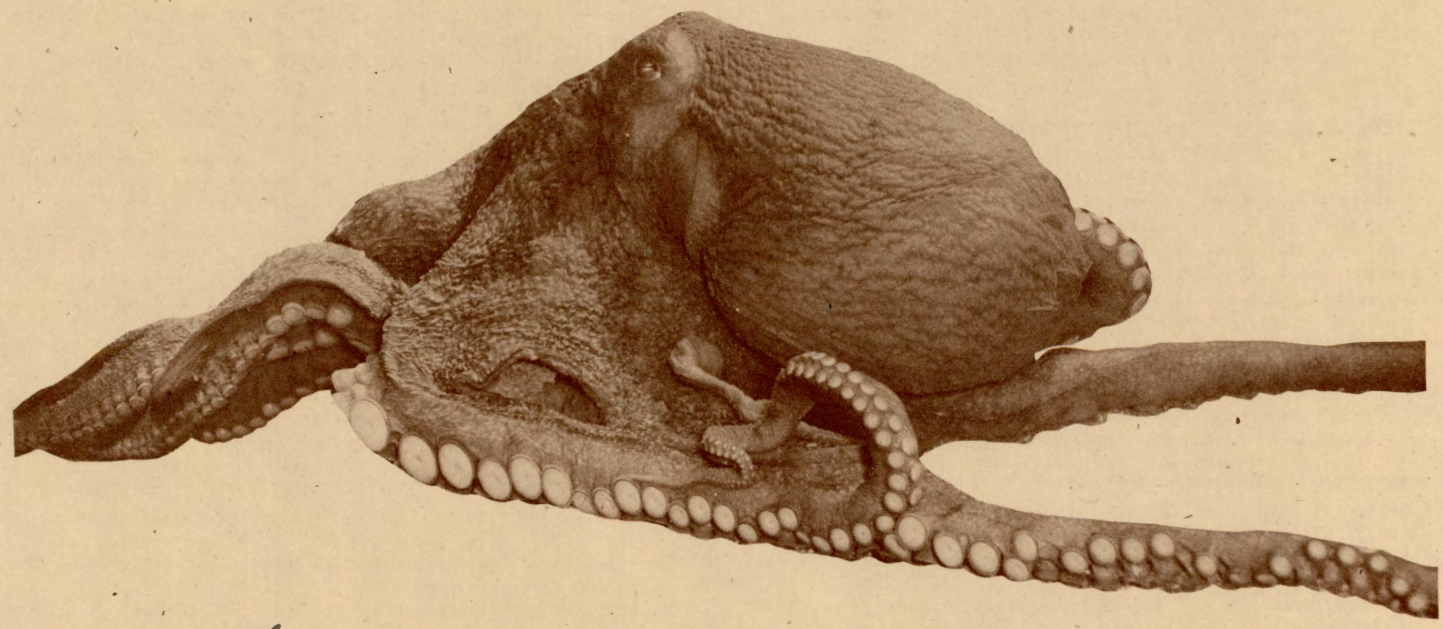

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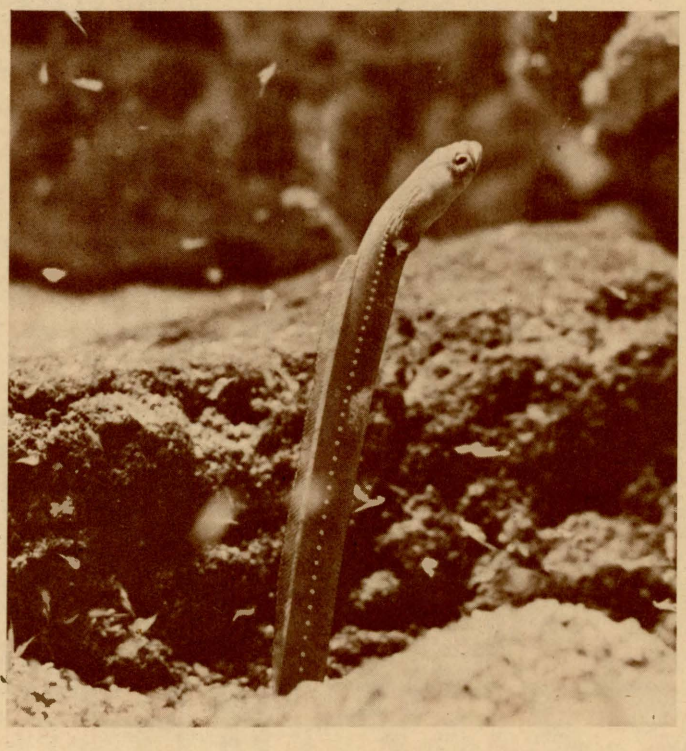

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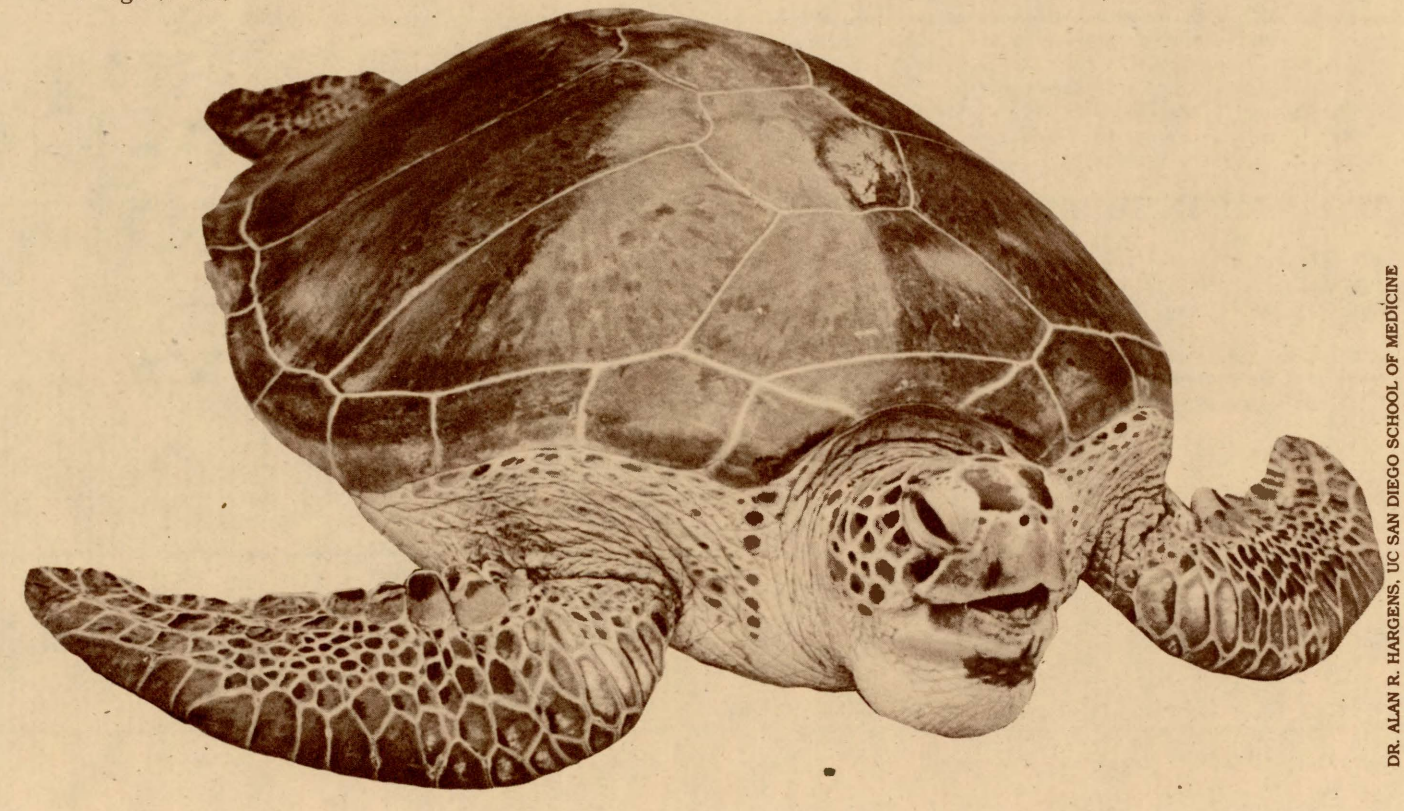

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Paul K. **Dayton**
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Neurobiology
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*Also Vice Chancellor of Marine Science and Dean of Marine Science.
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    - Army Corps of Engineers
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    - Naval Air Development Center
    - Naval Ocean Systems Center
    - Naval Oceanographic Office
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APPENDIX C

Major Awards and Honors

Sir Edward C. Bullard
Received Maurice Ewing Medal from the American Geophysical Union

Dr. James T. Enright
Awarded Fulbright-Hays Fellowship by the U.S. Department of State

Dr. David M. Gardiner
Received Eckart Dissertation Prize from Scripps Institution of Oceanography, University of California, San Diego

Dr. Harold T. Hammel
Appointed a foreign scientific member of the Max Planck Institute for Physiological and Clinical Research, Federal Republic of Germany

Dr. Carl L. Hubbs
Elected to honorary membership in the Explorers Club

Dr. Gerald L. Kooyman
Elected Fellow of the American Association for the Advancement of Science

Richard D. Methot, Jr.
Received jointly the first E. W. Fager Memorial Award from Scripps Institution of Oceanography, University of California, San Diego

Dr. Jerome Namias
Elected Fellow of the Explorers Club

Dr. William A. Nierenberg
Awarded the 1977 William Procter Prize by Sigma Xi, The Scientific Research Society of North America

Dr. Richard H. Rosenblatt
Named to a National Academy of Sciences committee to advise President Carter on the ecological perils of a sea-level canal

Dr. Per F. Scholander
Received honorary Doctor of Science degree from the Uppsala University, Sweden

Dr. Francis P. Shepard
Received honorary Doctor of Science degree from the University of Southern California

Jeffrey L. Star
Received jointly the first E. W. Fager Memorial Award from Scripps Institution of Oceanography, University of California, San Diego

Dr. Claude E. ZoBell
Received a citation from the International Symposium on Marine Microbiology, Spain

APPENDIX D

RESEARCH VESSELS OF SCRIPPS INSTITUTION OF OCEANOGRAPHY

	Alpha Helix	Melville	New Horizon	Ellen B. Scripps	Thomas Washington	FLIP	ORB
Type:	oceanographic research (biological)	oceanographic research	oceanographic research	offshore supply	oceanographic research	floating instrument platform	oceanographic research buoy
Hull:	steel	steel	steel	steel	steel	steel	steel
Year built:	1965-66	1969	1978	1964-65	1965	1962	1968
Year acquired by Scripps:	1966	1969	1978	1965	1965	1962	1968
From whom acquired:	National Science Foundation	U.S. Navy	State of California	Dantzler Boat and Barge Co.	U.S. Navy	Gunderson Bros. Shipbuilding Co.	U.S. Navy
Owner:	University of California	U.S. Navy	University of California	University of California	U.S. Navy	U.S. Navy	U.S. Navy
Length (ft.):	133′	245′	170′	95′	209′	355′	69′
Beam (ft., in.):	31′	46′	36′	24′	39′5″	20′	45′
Draft (ft., in.):	10′5½″	16′	11′	6′	14′5″	11′/300′	fwd. 4′10½″ aft 5′4½″
Displacement: Tons (full):	512	2,075	800	234	1,362	1,500 (vertical)	325
Cruising speed:	10	10	12	9	11	varies[1]	varies[1]
Range (miles):	7,200	9,181	7,000	5,100	10,000	varies[1]	varies[1]
Endurance (days):	30	41	30	14	36	30	30
Crew:	12	19-20	12	5	19	6	5
Scientific party:	12	30	13	8	23	10	10

[1]Depends upon towing vessel

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.

1977-78 Total days at sea: 976
1977-78 Nautical miles steamed: 92,691

APPENDIX E

Doctor of Philosophy Degrees Awarded in 1977-78 With Titles of Dissertations

Earth Sciences
Steven M. Day, "Finite Element Analysis of Seismic Scattering Problems."
Marcia K. McNutt, "Continental and Oceanic Isostasy."

Marine Biology
George W. Boehlert, "Physiological and Morphological Adaptations in the Surface-to-Benthic Migration of *Sebastes diploproa* (Pisces, Scorpaenidae)."
Robert E. Hodson, "On the Role of Bacteria in the Cycling of Dissolved Organic Matter in the Sea."
G. David Johnson, "Limits and Relationships of the Lutjanidae and Associated Families."
David M. Karl, "A Study of Microbial Biomass and Metabolic Activities in Marine Ecosystems: Development of Sensitive Techniques and Results of Selective Environmental Studies."
Arthur C. Ley, "The Organization of the Photochemical Apparatus of Photosynthesis in the Red Alga *Porphyridium cruentum*."
Thomas W. Okita, "Studies on the Effect of Silicate on the Synthesis of DNA Polymerases and Soluble Proteins of the Diatom *Cylindrotheca fusiformis*."
Edward G. Ruby, "Ecological Associations of the Marine Luminous Bacteria."

Oceanography
Meinrat O. Andreae, "The Marine Biogeochemistry of Arsenic."
David G. Aubrey, "Statistical and Dynamical Prediction of Changes in Natural Sand Beaches."
James A. Bailard, "An Experimental Study of Granular-Fluid Flow."
Brock B. Bernstein, "Selective Pressures and Coevolution in a Kelp Canopy Community in Southern California."
David M. Checkley, Jr., "The Egg Production of a Marine Planktonic Copepod in Relation to Its Food Supply."
Gérard Y. Conan, "Life History, Growth, Production and Biomass Modelling of *Emerita analoga*, *Nephrops norvegicus*, and *Homarus vulgaris* (Crustacea, Decapoda)."
Steven L. Costa, "Sediment Transport Dynamics in Tidal Inlets."
Kathleen Crane, "Hydrothermal Activity and Near-Axis Structure at Mid-Ocean Spreading Centers."
Noël Davis, "Studies of the Southern California Nearshore Sand Bottom Community."
Reinhard E. Flick, "Study of Shoaling Waves in the Laboratory."
Gregory W. Geehan, "Nearshore Sand Bars in the Gulf of California."
Chris M. Ireland, "The Chemistry of Some Opisthobranch Molluscs."
Linda L. Jones, "The Life History Patterns and Host Selection Behavior of a Sponge Symbiont, *Membranobalanus orcutti* (Pilsbry) (Cirrepedia)."
Arthur W. Kendall, Jr., "Relationships among American Serranid Fishes based on the Morphology of their Larvae."
Julian P. McCreary, Jr., "Eastern Ocean Response to Changing Wind Systems."
Michael E. Parke, "Global Numerical Models of the Open Ocean Tides M2, S2, K1 on an Elastic Earth."
Pavel Pistek, "Conductivity of the Ocean Crust."
Paola M. Rizzoli, "Solitary Rossby Waves over Variable Relief and their Stability Properties."
Kurt F. Schmitt, "Structure of the Marine Surface Layer."
Joseph F. Siebenaller, "Adaptation to the Deep-Sea Environment: The Patterning and Role of Genetic Variations."
James W. Stork, "Part I — Anthropogenic Angular Momentum and Its Relation to Severe Meteorological Events Part II — The Detection of Conductivity Anomalies in the Ocean."
Stephen J. Wratten, "Secondary Metabolites of *Chondria californica*, *Ulosa* sp., and *Pseudaxinyssa pitys*."

Master of Science Degrees Awarded in 1977-78

Earth Sciences
Carolynn Nelson
Jurgen Strehlau

Marine Biology
Charlene E. Brinkman

Oceanography
Mark E. Andersen
Jean-Loic Carré
Michael C. Karas
Tien-How Lee
Julie A. Michaelsen
José Pelaez-Hudlet

SIO Graduates 1977-78

Student Name and New Position

Meinrat O. **Andreae**
Assistant Professor
Florida State University
Tallahassee, Florida
David G. **Aubrey**
Assistant Scientist
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts
James A. **Bailard**
Postgraduate Research Oceanographer
Ocean Research Division-SIO
Brock B. **Bernstein**
Postdoctoral Fellow
Dalhousie University
Halifax, Nova Scotia
George W. **Boehlert**
Postdoctoral Fellow
National Marine Fisheries Service
Seattle, Washington
David M. **Checkley**, Jr.
Postdoctoral Fellow
Marine Laboratory
Aberdeen, Scotland
Gérard Y. **Conan**
Centre Oceanologique de Bretagne
Brest, France
Steven L. **Costa**
Postgraduate Research
Institute of Marine Resources-SIO
Kathleen **Crane**
Postdoctoral Fellow
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts
Noël **Davis**
Chamber Consultants & Planners
Stanton, California
Steven M. **Day**
Systems Science & Software
San Diego, California
Reinhard E. **Flick**
Assistant Research Oceanographer
Ocean Research Division-SIO
Gregory W. **Geehan**
EXXON Oil Company
Houston, Texas
Robert E. **Hodson**
Assistant Professor
University of Georgia
Athens, Georgia
Chris M. **Ireland**
Postdoctoral Fellow
University of Hawaii
Honolulu, Hawaii

G. David **Johnson**
Postdoctoral Fellow
Smithsonian Institution
Washington, D.C.
Linda L. **Jones**
Marine Mammal Commission
Washington, D.C.
David M. **Karl**
Assistant Professor
University of Hawaii
Honolulu, Hawaii
Arthur W. **Kendall**, Jr.
Sandy Hook Marine Sport Fisheries Laboratory
Highlands, New Jersey
Arthur C. **Ley**
Postdoctoral Fellow
UC San Diego
La Jolla, California
Julian P. **McCreary**, Jr.
Assistant Professor
Nova University
Dania, Florida
Marcia K. **McNutt**
Assistant Professor
University of Minnesota
Minneapolis, Minnesota
Thomas W. **Okita**
Postdoctoral Fellow
UC Davis
Davis, California
Michael E. **Parke**
Pacific Marine Environmental Laboratory
National Oceanic and Atmospheric Administration
Seattle, Washington
Pavel **Pistek**
Postgraduate Research Oceanographer
Ocean Research Division-SIO
Paola M. **Rizzoli**
Research Scientist
Consiglio Nationale delle Ricerche
Venice, Italy
Edward G. **Ruby**
Postdoctoral Fellow
Harvard University
Cambridge, Massachusetts
Joseph F. **Siebenaller**
Postdoctoral Fellow
State University of New York
Stony Brook, New York
James W. **Stork**
Postgraduate Research
Institute of Marine Resources-SIO
Stephen J. **Wratten**
Postdoctoral Fellow
Cornell University
Ithaca, New York

APPENDIX F

The Regents of the University of California

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Mervyn M. Dymally
Lieutenant Governor of California
Leo T. McCarthy
Speaker of the Assembly
Wilson Riles
State Superintendent of Public Instruction
Cheryl F. Biles
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Forrest A. Plant
Vice President of the Alumni Association of the University of California
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President of the University

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Vilma S. Martinez
Verne Orr
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Harry R. Wellman
Vice President of the University, Emeritus; Professor of Agricultural Economics, Emeritus; and Agricultural Economist, Emeritus
Frank L. Kidner
Vice President — Educational Relations, Emeritus; and Professor of Economics, Emeritus
John A. Perkins
Vice President — Business and Finance, Emeritus; and Professor of Political Science, Emeritus
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University Provost, Emeritus; Chancellor at Santa Cruz, Emeritus; and Professor of Mathematics, Emeritus
Robert M. Underhill
Vice President, Emeritus; and Secretary and Treasurer of The Regents, Emeritus
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Treasurer of The Regents, Emeritus
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General Counsel of The Regents, Emeritus
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Chancellor at Los Angeles
Ivan Hinderaker
Chancellor at Riverside
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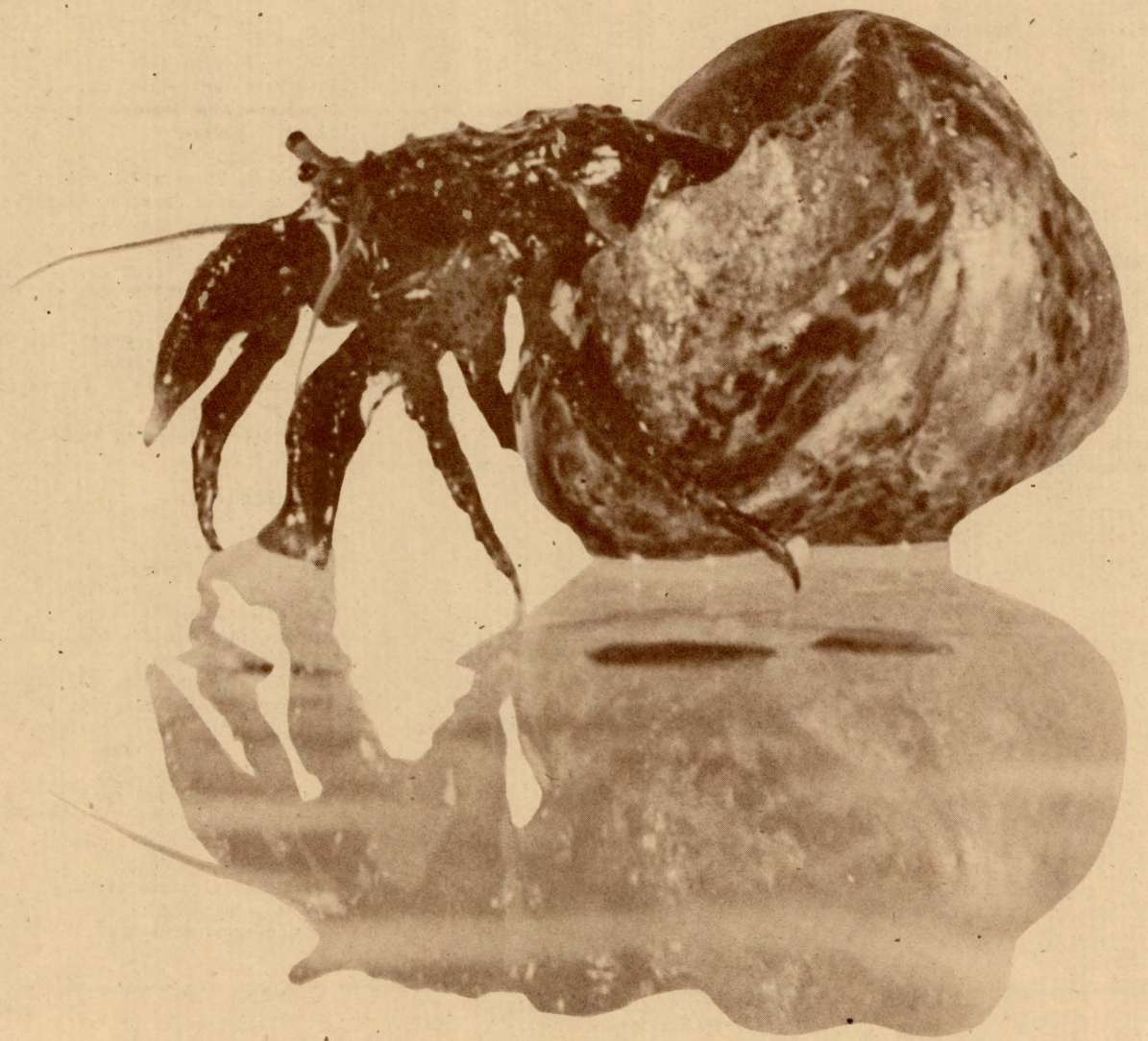
Chancellor at San Diego
Francis A. Sooy
Chancellor at San Francisco
Robert A. Huttenback
Chancellor at Santa Barbara
Robert L. Sinsheimer
Chancellor at Santa Cruz

APPENDIX G

Current Funds Expenditures 1977-1978

Agency	Institutes			Total	Percentage of Total
	Scripps Institution of Oceanography	Geophysics and Planetary Physics	Marine Resources		
FEDERAL GOVERNMENT					
National Science Foundation	$25,145,446	448,206	408,034	26,001,686	57.9
Navy, Department of the	4,625,332	690,647	142,816	5,458,795	12.2
National Oceanic and Atmospheric Administration	369,627	-0-	1,116,387	1,486,014	3.3
Energy, Department of	243,844	91,004	462,824	797,672	1.8
Air Force, Department of the	443,061	32,245	-0-	475,306	1.1
National Institutes of Health	302,062	-0-	2,249	304,311	0.7
Other	638,547	178,447	27,703	844,697	1.9
Total Federal Government	31,767,919	1,440,549	2,160,013	35,368,481	78.9
STATE AND LOCAL GOVERNMENT	5,776,812	200,351	872,886	6,850,049	15.2
PRIVATE GIFTS AND GRANTS	1,843,732	91,272	55,004	1,990,008	4.4
ENDOWMENT FUNDS	611,289	24,649	2,328	638,266	1.4
Total Current Funds Expenditures	$39,999,752	1,756,821	3,090,231	44,846,804	100.0



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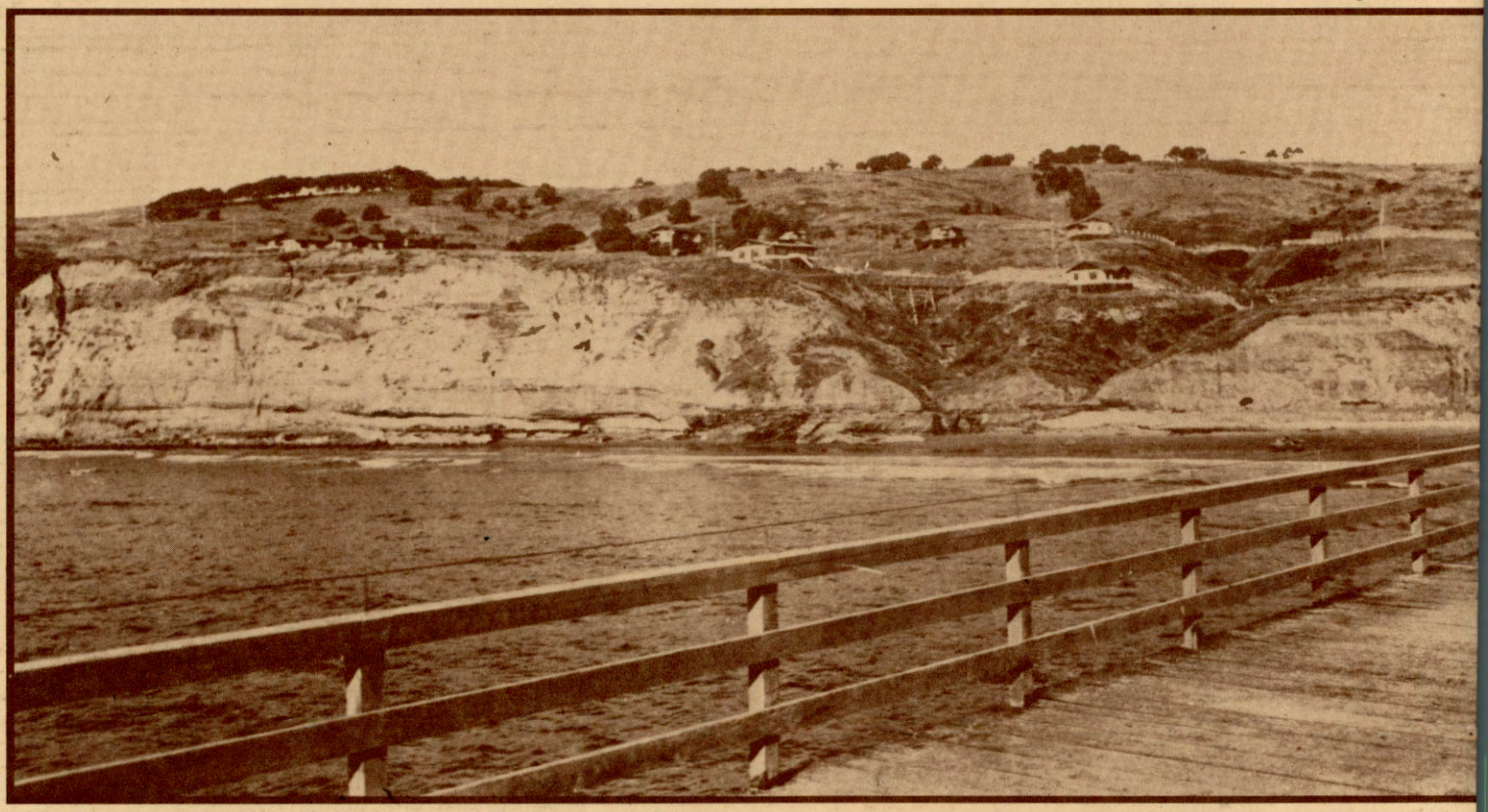

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