Scripps Institution of Oceanography 1979

University of California, San Diego

DEDICATION

He has been chased by Burmese gunboats and by typhoons; he likes both his music and explosives noisy; and he urges Tabasco sauce on almost everything—he finds the empty bottles useful for balancing hydrophones. He is one of those oceanographers who has visited many of the exotic Pacific isles; in fact, he broke his leg while getting into a longboat while leaving Pitcairn after energetically climbing about the island.

Dr. Russell W. Raitt became an oceanographer in 1941, when he joined the University of California Division of War Research (UCDWR), San Diego. He received his Ph.D. in physics in 1935 from Caltech and there worked in seismic exploration for six years. His experience on land was carried into similar researches at sea for UCDWR: reflection of sound from the ocean surface and bottom; reverberation of sound in the sea; and the generation, transmission, and attenuation of explosive impulses in the sea.

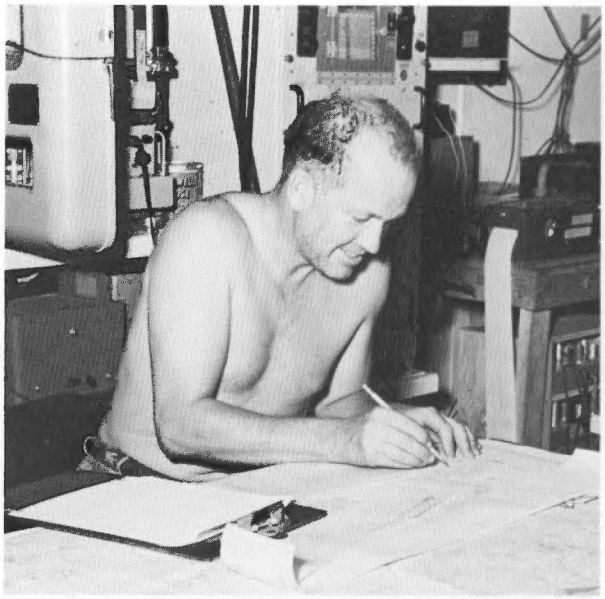
Dr. Raitt was one of the three who, in 1942, discovered the puzzling "false bottom" that has become known as the deep scattering layer.

After World War II Dr. Raitt continued his seismic studies at the Marine Physical Laboratory (MPL). He became an associate professor at Scripps in 1949, after MPL had become a unit of the institution.

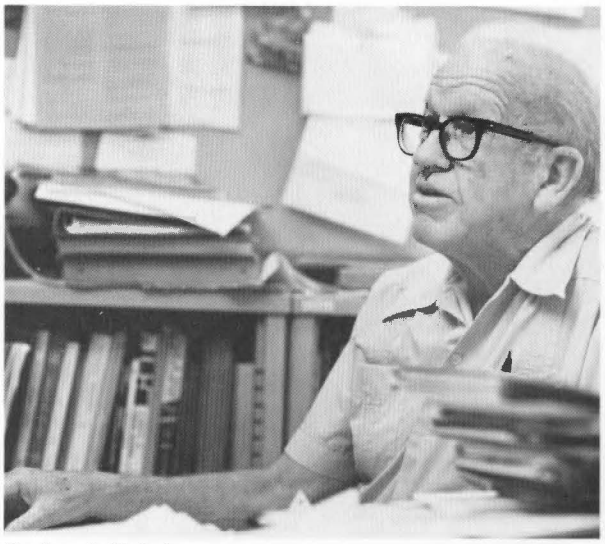
Dr. Raitt was a pioneer in developing techniques for using sound transmissions to study the geologic structure of the ocean floor, down to the Mohorovičić discontinuity. His favored tool has long been explosives, especially in large bursts. On Scripps's first postwar expedition, Midpac, he carried out 2,000 km of seismic-refraction profiles in the Pacific Ocean. On Capricorn Expedition in 1952 he enthusiastically carried out more profiles. These surveys established the basic structure of the Pacific crust and showed that the sediments of the Pacific basin were both far thinner than had been predicted and thinner than those of the Atlantic basin. On those early expeditions Dr. Raitt also carried out seismic surveys of Bikini and Enewetak atolls, which provided strong evidence that the features were submerged volcanic peaks. This was later confirmed by drilling.

Throughout the 1950s and 1960s Dr. Raitt continued to develop and apply seismic-reflection and seismic-refraction techniques to investigations of the crustal layers and the upper mantle in the ocean basins, the marginal seas, and ocean trenches. He participated in the search for a suitable drilling site for Mohole, and endorsed a location near Hawaii before the project was abandoned. His explorations have taken him on many expeditions throughout the Pacific and Indian oceans.

In the latter 1960s Dr. Raitt began investigating, by means of seismic refraction, the suggestion that the uppermost mantle in the ocean exhibits elastic anisotropy. At times the shipboard frenzy involved simultaneously sending a large balloon upward, a deep mooring downward, and a hydrophone array sternward. The measurements taken at several locations showed that anisotropy does exist and that the direction of maximum velocity is in the direction of sea-floor spreading.



Dr. Russell W. Raitt at work aboard R/V Spencer F. Baird *during the 1952-1953 Capricorn Expedition.*



Dr. Russell W. Raitt

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Cover photo: R/V New Horizon *by ©Terry Wilmot.*

SCRIPPS INSTITUTION OF OCEANOGRAPHY 1979

UNIVERSITY OF CALIFORNIA, SAN DIEGO

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INTRODUCTION

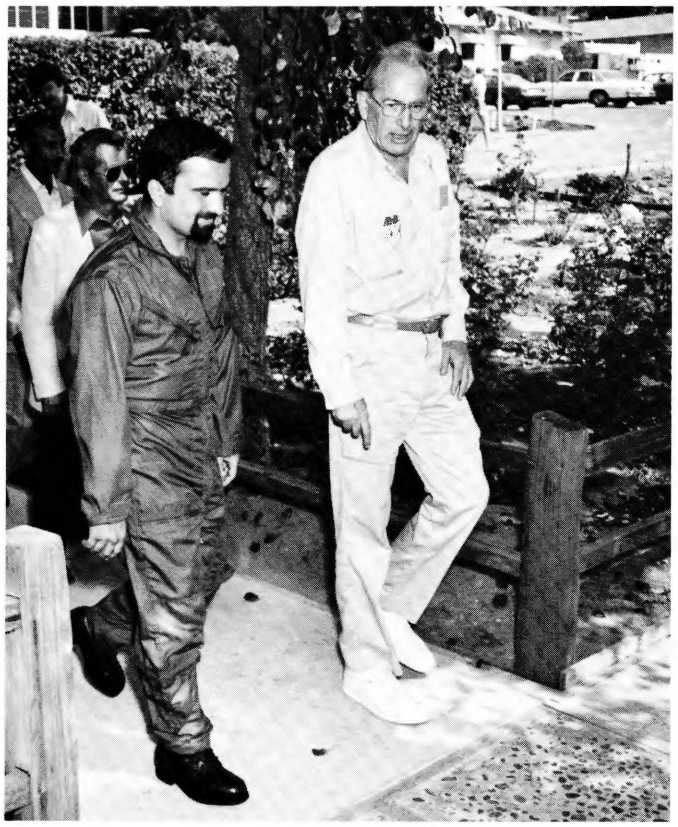
The year that passed, as usual, had its joys and its sorrows—but somehow, this year seemed to have more of both. The loss of Ruth Inman to our family was felt deeply by all of us. So was the passing of our two giants—the old one, Carl Hubbs, and the young one, Arnold Bainbridge.

Among the joys was the acceptance into the Scripps fleet of R/V *New Horizon*. It is a beautiful vessel that will be serving the institution long after most of us have retired.

As usual, there were many, many awards to members of our staff. The one we can be most proud of went to Walter Munk, who received the U.S. Navy's Captain Robert Dexter Conrad Award. This was the same award that Fred Spiess received in 1974.

This was the year when Scripps took its first big step into space by initiating the acquisition of its satellite-oceanographic facility.

In the way-out area, Scripps has become host to DUMAND and their workshop was held here.



Crown Prince Hassan of Jordan, left, and Dr. William A. Nierenberg, right, during the prince's impromptu visit to Scripps.

Our relations with the People's Republic of China are developing at a rapid tempo as they are everywhere else. We had two groups from the People's Republic visiting at Scripps and scientists from Scripps went there.

For a number of years I have noted in these introductory paragraphs how climate and the interest in climate would become an intensified part of our efforts as the rest of the scientific world also has recognized that it is largely an oceanographic problem.

A closely related subject is the carbon dioxide problem, particularly in its atmospheric manifestation. Because of the debate that is swirling around on choices between the various forms of energy, this is becoming a more and more dominant factor in research at Scripps. The principal change in the institution is in tempo. The importance of these researches has long been recognized by the institution and many of the basic results on which deliberations rest originated here.

Finally, this is the year that we received the very generous $1,500,000 Fleischmann Foundation grant. This is to be spent within five years for the acquisition of major pieces of advanced research equipment.

William A. Nierenberg

William A. Nierenberg, Director
Scripps Institution of Oceanography

SCRIPPS INSTITUTION OF OCEANOGRAPHY 1979

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

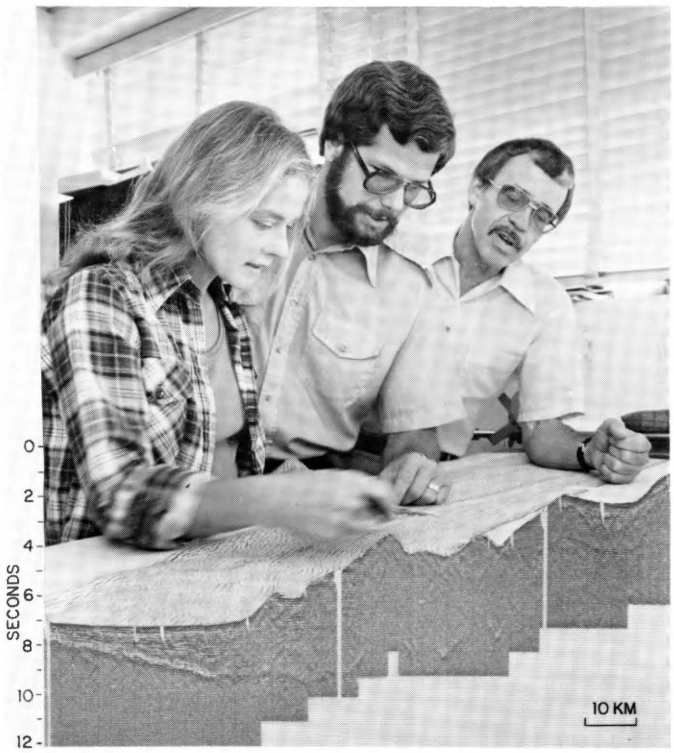
Many of the investigations of scientists in the Geological Research Division depend on new and sophisticated items of equipment for measuring physical and chemical properties of sediments and rocks. Yet, substantial progress in understanding the earth and its processes is made using procedures as simple as breaking off a piece of rock with a hammer and examining it with a hand lens.

Dr. LeRoy M. Dorman led the ocean bottom seismology group on the Rivera Ocean Seismic Experiment (ROSE), a five-ship multinational event. More than seventy ocean bottom instruments were utilized to study the earthquakes that occur on the East Pacific Rise southwest of Mexico, where the lithospheric Cocos Plate is formed. The same set of instruments served as receivers during a large-scale, seismic-refraction experiment designed to reveal the elastic properties of the Cocos Plate as it ages and travels toward its eventual destruction at the earthquake belt marking Mexico's west coast. Mexican and United States field parties on land augmented the permanent seismic stations ashore with portable instruments.

Dr. John A. Orcutt participated in ROSE, a program with the goal of completing a detailed structural and microearthquake survey along a major oceanic rise crest. During the Rivera Submersible Experiment (RISE) with Dr. Kenneth C. Macdonald, submersible *Alvin*, operated by Woods Hole Oceanographic Institution, Massachusetts, was used as a source of seismic waves for a small ocean bottom seismometer array. From this data they will learn a great deal about the very shallow structure of the crust and the influence of cracking and porosity on physical properties. Drs. Orcutt, Robert L. Parker, and Jan D. Garmany completed various studies that relate seismic travel time observations to earth structure. A study was made in collaboration with Dr. Paul A. Spudich on the nature of propagation of shear waves in the oceanic crust and consequent constraints on porosity and cracking. Dr. Orcutt also completed a long term study that demonstrated the seismic noise at the sea floor is very similar to that observed on the continents.

Dr. Macdonald's activities centered around diving programs using *Alvin*. On the Mid-Atlantic Ridge unusual magnetic anomalies were studied along the rift valley axis using a magnetic gradiometer operated on *Alvin*. On the East Pacific Rise, 21°N, Drs. Macdonald and Orcutt deployed ocean bottom seismometers in a triangular array. *Alvin* then "shot" to the instruments using a hydraulic impact hammer. This high resolution seismic experiment should allow them to study shallow crustal structure in the vicinity of active hydrothermal vents ($\sim$400°C) found along the spreading center.

In another study Drs. Joseph R. Curray, Frans J. Emmel, David G. Moore, Gregory F. Moore, and George G. Shor, Jr., and graduate students have continued their investigation of the northeast Indian Ocean and southeast Asian region. They worked on analysis and publication of the results. Drs. G. F. Moore, Curray, and Shor, in collaboration with Sugiarta Wirasantosa, a visiting Indonesian geologist, continued investigation of the subduction processes in the Sunda Trench. Dr. G. F. Moore has been analyzing processed multichannel seismic-reflection profiles across the trench slope west of Sumatra, which show that the trench sediment wedge is scraped from the descending oceanic plate and accreted to the inner trench slope.



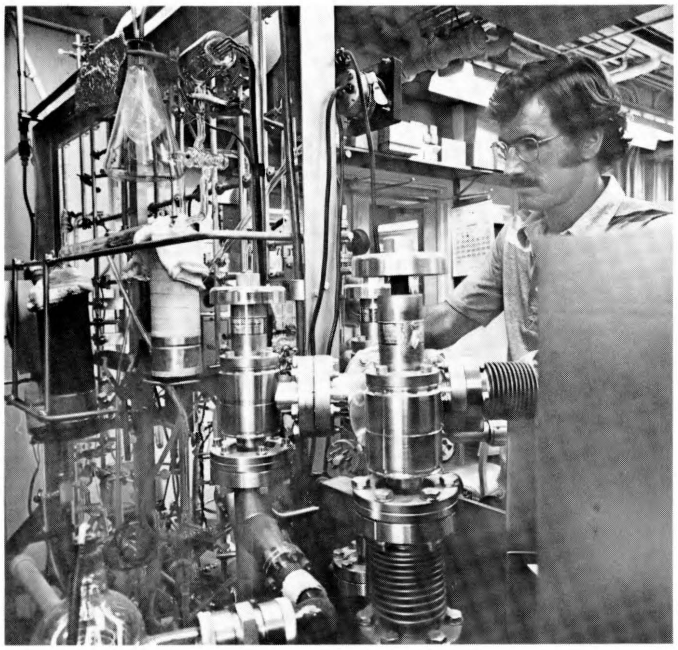
Drs. Joseph R. Curray (right), Gregory F. Moore, and graduate student Desiree Beaudry examine a seismic refraction profile. At bottom of picture is enlarged multifold seismic reflection profile from across the lower slope of the Sunda Trench west of Sumatra, Indonesia, collected on R/V Thomas Washington. *Oceanic crustal reflector can be traced approximately 25 km landward beneath the subduction complex.*

Drs. G. F. Moore, Curray, and D. G. Moore also studied geophysical profiles across the arc in the region between Burma and Timor to understand the relationship between style of accretion and deformation with variations in sediment thickness on the subducting plate and subduction direction. In general, where a thinner sediment section overlies the underthrusting plate, the offscraping process more intensely deforms the accreted sediment, as south of Java. Farther to the west and north, where the sediment section overlying the subducting Indian Plate approaches 10 km in thickness, the accreted sediment is deformed into rather gentle folds, striking parallel to the trench axis.

Graduate student Robert M. Kieckhefer and Drs. Shor and Curray have completed a preliminary interpretation of seismic-refraction measurements off central Sumatra from seaward of the trench to the continental shelf of Sumatra. This shows the steeply dipping oceanic crust and mantle following the apparent Benioff zone beneath the forearc basin. Determination of crustal type beneath the forearc basin is not yet definitive. Drs. Emmel, Curray, and D. G. Moore have completed several publications on various aspects of channel migrations in the Bengal Deep-Sea Fan, structure in the Bengal geosyncline, and spreading and crustal structure in the Andaman Sea.

The Isotope Laboratory research group, Drs. Harmon Craig, Yu-chia Chung, and John E. Lupton, continued studies of mantle volatiles and geothermal fluids on land and at sea and with the Indian Ocean GEOSECS program. Dr. Craig, Valerie K. Craig, and graduate students carried out a detailed sampling program at Yellowstone National Park, Wyoming, and mapped a new thermal activity in the Mud Volcano area resulting from a series of recent earthquakes.

Dr. Lupton continued collaborative studies with New Zealand



Dr. John E. Lupton attaches a RISE Program submarine-vent water sample to the mass spectrometer inlet system for He^3/He^4 analysis.

scientists on helium isotope ratio variations in the quite different tectonic regime of New Zealand geothermal areas and volcanoes. They began mapping this ratio in dissolved helium in Indian Ocean waters sampled during the GEOSECS legs on Indopac Expedition. Graduate students Robert J. Poreda and John A. Welhan studied gases from Iceland and confirmed the very high He^3/He^4 ratios (about 18 times atmospheric) reported by Russian scientists. This "hot-spot type" helium has now been observed in gases from Yellowstone National Park; Kilauea fumarole, Hawaii; and the Ethiopian Rift Valley; as well as in Iceland; which indicates that a very distinctive helium signature characterizes such areas as distinct from ocean-ridge basalts that have ratios only about ten times atmospheric.

This group continued the study of gases and isotopes in submarine hydrothermal systems, with studies of gases in Guaymas Basin, Gulf of California, cores from Deep Sea Drilling Project holes, and in the very high temperature ($\sim$400°C) emanations at 21°N on the East Pacific Rise collected during the RISE Program. Injected mantle helium, He^3/He^4 $\sim$7 times atmospheric, was observed in both areas and high methane concentrations were measured in the 21°N RISE samples, which indicated that CH_4 may also be a good tracer, possibly in situ, for deep-ocean geothermal activity.

Drs. Craig and Chung and graduate student Kyung-Ryul Kim participated in the final GEOSECS seagoing work at the original GEOSECS-I station in the North Pacific where the program began ten years ago. Dr. Chung and Dr. Robert C. Finkel carried out a very detailed radioisotope sampling program for a variety of experimental programs. Kim, Dr. Craig, and Valerie Craig conducted a massive gas-extraction program to collect argon from a profile of 1.8 metric ton seawater samples for a new program. This program will apply the cosmic-ray produced isotope Ar-39 to oceanographic studies.

Dr. Chung completed work on lead-210 and radium-226 variations in the Pacific GEOSECS program. New data from the Indian Ocean expedition support the discovery of the large Pb-210 deficiency vs. radium and the very short deep-ocean residence time of lead because of particulate scavenging in deep water.

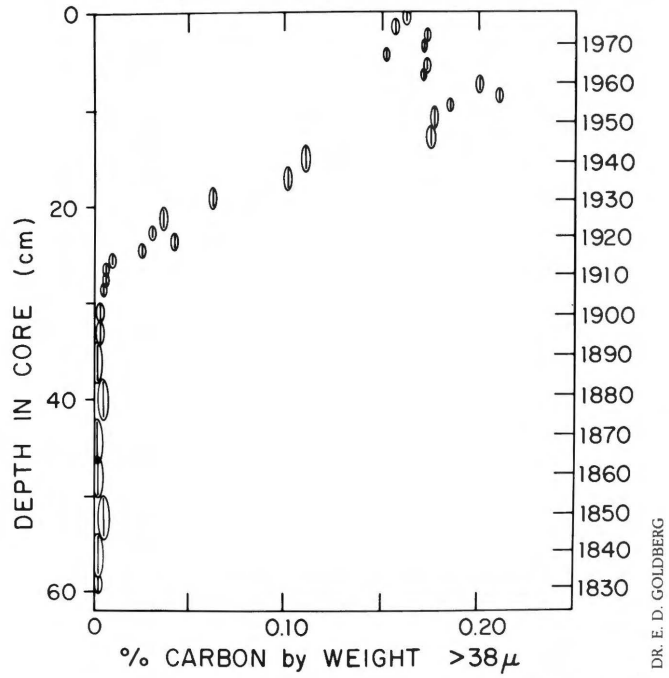
Also in the isotope laboratory, Dr. Robert D. Willis is working on measuring Ar-39 in ocean water samples by the "single atom counting" laser technique. Ar-39 is the last remaining major radioactive tracer for ocean studies, and its half-life (270 years) makes it ideal for study of the entire range of time scales below the mixed layer.

In another laboratory, Drs. John J. Griffin and Edward D. Goldberg are studying the history of burning. The amounts and types of fossil fuel and wood burning are recorded in lacustrine and coastal marine sediments on the bases of the morphologies and dimensions of the carbon (soot) particles accommodated therein. The surface of the oil carbons shows a convoluted, layered structure, whereas the coal and wood carbon surfaces are homogenous with little characteristic fine structure. Wood carbons had length to width dimensions in general greater than three.

In sediments from Lake Michigan, where both natural and anthropogenic materials from a highly industrialized area accumulate, there were marked increases in the soot particles from the early 1920s to the present. The sedimentary strata deposited before 1900 contain carbon particles derived from plant and wood burning. In the early decades of the 1900s, the sediments reveal coal burning became a dominant source of carbon particles. More recently the carbon particles show morphologies with characteristics of oil burning to a large extent. During this period, the elemental carbon content of the sediments increased from 0.05 to 0.25%.

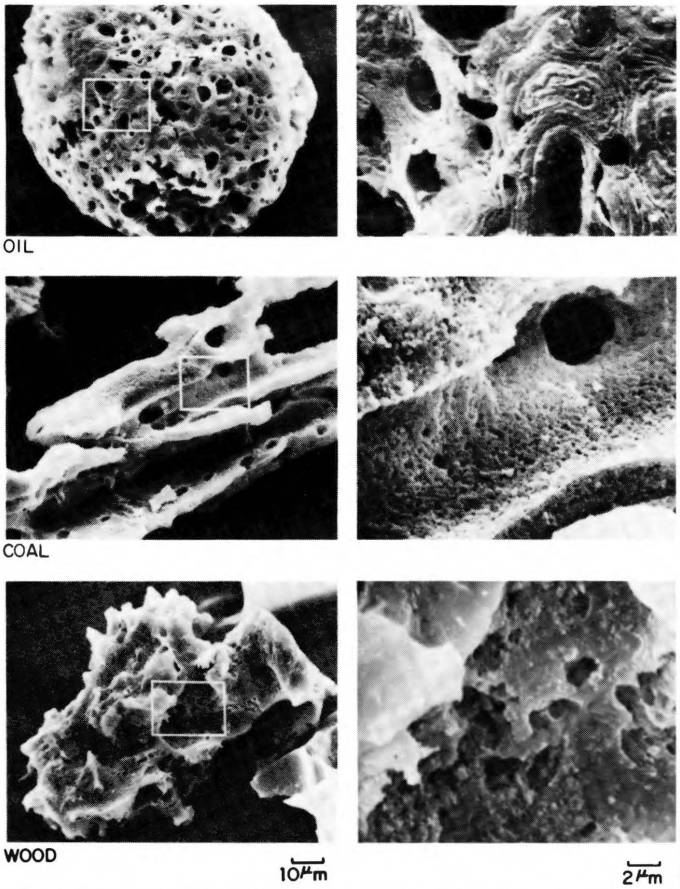
Some metals show parallel increases to the carbon and are related to the industrial activities associated with energy production. Lead, tin, cadmium, zinc, copper, iron, and manganese show markedly higher fluxes in recently deposited Lake Michigan sediments than in those accumulated in the 19th century.

The quality of coastal seawaters is not only determined by the concentrations of a variety of metals but also by their forms. Drs. Vernon F. Hodge and Goldberg and UC San Diego graduate student Sharon L. Seidel have investigated the forms of tin in seawater, primarily because this metal is dispersed by man at levels similar to the amounts of this element brought annually to the oceans from the rivers. Tin in California coastal waters exists as inorganic tin and as dimethyl tin in about equal amounts. The latter is a neuropoison and can in principle have impact upon higher organisms. The sources of the dimethyl tin are the plants of the sea. There are marked increases in tin contents of recently developed sediments over those of the previous century, probably arising from use of this metal in plating, as a biocide, and in a variety of industrial uses.



Concentration of elemental carbon particles (over 38 micron size fraction) in a sediment from southeastern Lake Michigan. The ages were determined by Pb-210 geochronology.

The marine geochemistries of uranium, plutonium, and polonium are being investigated by Minoru Koide and Drs. Hodge and Goldberg. They have discovered that the isotopic compositions of particulate uranium and of dissolved uranium in coastal waters are unique. Particulate uranium has a U-234/U-238 ratio of about one,



The morphologies of carbon particles produced by oil, coal, and wood burning are shown.

while the dissolved uranium has a value of the ratio of 1.15. The differences can be used to trace the paths of the two forms of uranium into and out of the marine biosphere.

For most of the biological samples studied, the U-234/U-238 ratio is less than that of dissolved uranium indicating that there is an uptake of the particulate form. The largest deviation is in scallops with a U-234/U-238 ratio of 0.96 that indicates that all of the uranium came from a particulate form. The ratio in algae ranges from 1.09-1.18, which indicates contributions from both dissolved and particulate uranium. Of interest is the linear relationship between the total plutonium content in the organisms and the particulate uranium content. Thus, the primary entry of plutonium into the organisms is probably through the particulate forms.

The accumulation of plutonium, polonium, and uranium upon surfaces (glass beads, filter paper, aluminum balls, and polyvinyl chloride sheets) as a function of time varies for each element. Although there is a linear uptake for each element, there are clear differences in uptake slopes. This difference suggests that the elements, although in particulate form, may not be associated with the same solid phases.

In yet another group, Dr. J. Douglas Macdougall and colleagues worked on a variety of problems in geochemistry. Of major importance was the acquisition of a new solid-source mass spectrometer that will be used in studies of the Sm-Nd and Rb-Sr systems in young oceanic and continental basalts, as well as in ancient crustal materials. The focus of work with this new instrument will be on investigations of the chemical structure and evolution of the earth's mantle through use of tracers. Work carried out by graduate student Richard W. Carlson in collaboration with Dr. Gunter W. Lugmair has indicated distinct isotope heterogeneity in the sources supplying the Columbia River basalts, based on Sr and Nd isotopic evidence.

Another aspect of work in this group involves U and Th isotope studies of young volcanic rocks. Fractionation processes in the magma chambers that feed volcanoes can be examined by investigating radioactive equilibrium among the U and Th isotopes. Drs. Macdougall and Finkel completed field work on the geologically young (<100,000 yrs) volcano, Mt. Shasta, in northern California. In collaboration with graduate student Sally Newman, they have begun analysis of the U and Th isotopic systems in a suite of rocks spanning Mt. Shasta's evolutionary history. Similar research is being conducted on very young oceanic ridge basalts in the hope that U-Th disequilibrium may provide a means to determine eruption chronology on a fine scale, as well as to detail fractionation processes occurring in ridge-crest magma chambers.

Investigations of carbonaceous chondrite meteorites have continued during the year. In this work, various aspects of the earliest history of these meteorites are being studied, with the goal of understanding conditions in the early solar system and, ultimately, their implications for the formation of the earth. An important finding of these studies has been the discovery of isotopic anomalies in small, refractory-element rich inclusions from the Murchison meteorite. The isotopic measurements are being carried out using the ion microprobe at the Johnson Space Center, Houston, Texas.

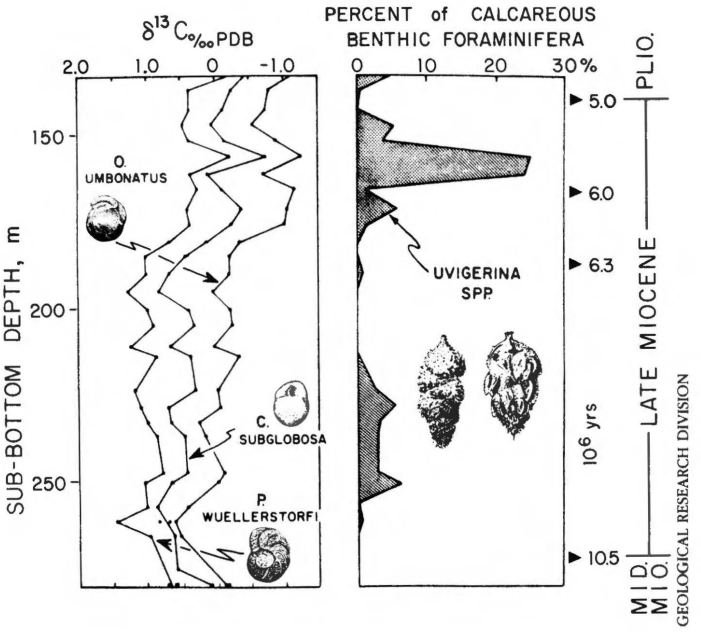
Numerous other investigations are also under way in this group: Jodi L. Carlson is investigating the thermal history of the Southern California Batholith using fission track methods; Dr. Gary M. McMurtry is studying the uptake of transition metals and actinides on particulate material; and various members of the group are conducting isotopic, chemical, and mineralogical studies of hydrothermal and igneous materials collected by submersible *Alvin* during the RISE Program.

The paleoceanography group, Drs. Wolfgang H. Berger, Edith S. Vincent, John S. Killingley, and William T. Coulbourn, and associates continued their studies on isotope stratigraphy, preservation stratigraphy, and biostratigraphy of deep-sea carbonates.

Extensive ^{14}C-dating of box cores led to the discovery of a thoroughly mixed benthic layer of rather uniform thickness, 8.5 cm ± 1 cm, in the deep-sea carbonates of the western equatorial Pacific.

The hunt for the meltwater spike continued. Deep-sea benthic foraminifera show major changes in abyssal conditions during and after deglaciation. However, the nature of these changes is not yet clear.

A combination of detailed biostratigraphy and isotope stratigraphy revealed the occurrence of a drastic change in oceanographic



Late Miocene carbon isotope stratigraphy of benthic foraminifera in the tropical Indian Ocean. A distinct drop in $\delta^{13}C$ values (about 0.8 o/oo) occurs near 180 m. An increase in the abundance of Uvigerina *coincides with the Carbon Shift.*

conditions approximately 6.2 million years ago, during the late Miocene Magnetic Epoch 6. The event, "Epoch-6 Carbon Shift," denotes a change in the fertility of the ocean.

The paleoceanographic studies by Dr. Hans R. Thierstein led to the discovery of a major shift in the isotopic composition of the calcitic shells of marine microorganisms across the Cretaceous-Tertiary boundary. This discovery indicates a rapid salinity drop or temperature rise accompanied by a fertility and oxygenation decrease of oceanic surface waters at a time of one of the most pronounced mass-extinction events in the history of life. This finding and the results from ongoing studies of the mid-Cretaceous oceanic anaerobism, and their similarities with known Cenozoic paleoceanographic events investigated by Dr. Berger's group has led Drs. Thierstein and Berger to propose a possibly important paleoceanographic and paleoclimatic mechanism: the reconnection of temporarily isolated basins in low and high latitude settings. Such events may well have been the cause of the sudden catastrophes preserved in the sedimentary record, to Cuvier's delight and Darwin's embarrassment.

Dr. Devendra Lal and associates, with a view to study prominent climatological changes, possibly related to variations in monsoon dynamics, studied several Bay of Bengal and equatorial Indian Ocean cores for a suite of major and minor trace elements, including U and Th. Only the equatorial cores could be satisfactorily dated using the ionium method; the clay accumulation rates were determined to lie in the range 1.3-7.4 mm/10^3 yrs.

In collaboration with Dr. Berger, several box cores collected from the Ontong Java Plateau in the Pacific Ocean were studied for their chronology and bioturbation features. Radionuclides measured were: Pb^{210}, C^{14}, Th^{230}, and Th^{232}. These analyses have also proved important in the evaluation of effects of "erosion" in carbonate accumulation.

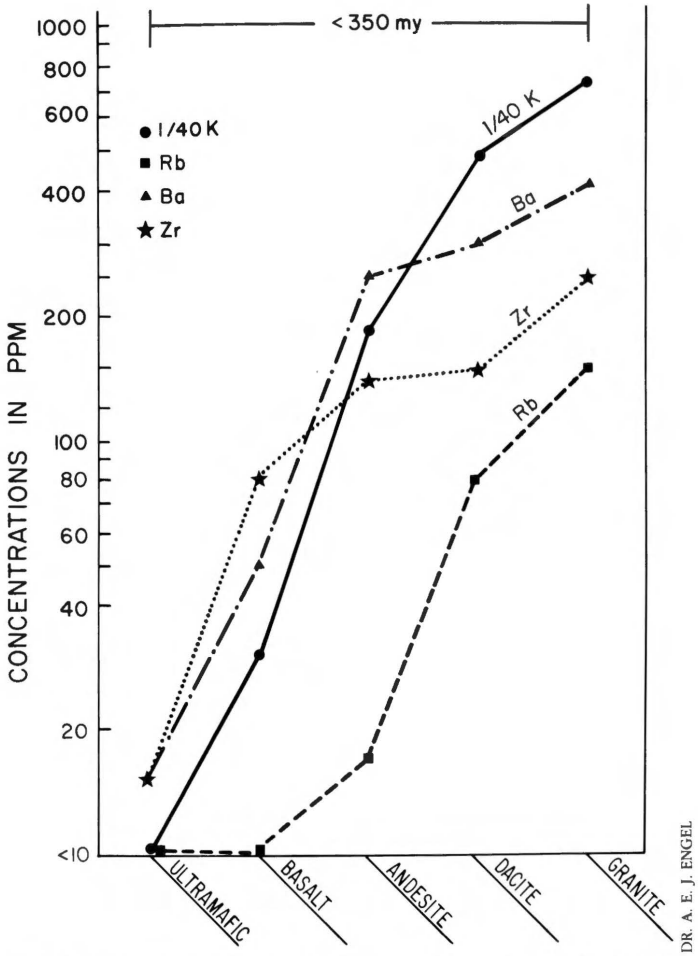
Several large Central Pacific manganese nodules of surface area exceeding 50 cm^2 are being dated with the Be^{10} method; the measurement methods include the newly developed accelerator method. Chronologically marked large size nodules seem promising to scientists for study of a number of important geophysical and geochemical changes in the past tens of million years.

The available global data on specific activity of Si^{32} in surface and near-surface waters reveal that studies of this radioisotope are useful for characterizing the nature of upwelling in coastal regions.

Dr. William R. Riedel's work on marine microfossils is concentrated on two groups—the siliceous skeletons of the single-celled radiolarians and microscopic skeletal debris (ichthyoliths) derived principally from pelagic fishes. In collaboration with Annika B. Sanfilippo, Dr. Riedel is redefining the radiolarian genera and species that have proved most useful for stratigraphic correlation, made necessary by the increasingly stringent requirements for recognizing precise time horizons in cores obtained by the Deep Sea Drilling Project. They are also studying the radiolarians in the section at Gubbio, Italy, which has become the standard reference for magnetic and microfossil stratigraphies of the late Cretaceous. Together with Patrick De Wever, Université des Sciences et Techniques de Lille, France, they have described radiolarians from the Triassic, until now one of the least known periods in the history of this group of organisms. In all of these studies scientists are using the newly developed microcomputer system to assist in the storage and retrieval of alphanumeric data, as well as images of the fossils, thereby improving the reliability of paleontologic information and its interpretation.

With Dr. Riedel, Patricia S. Doyle has completed a compilation of the geographic and stratigraphic distribution of all of the 105 ichthyoliths that have been described to date. This will form a springboard for investigations into the origin of these poorly understood microfossils and will help in selecting the most promising forms for more detailed stratigraphic studies.

In a different field, studies of the geologic evolution of Afro-Arabia, by Dr. Albert E. J. Engel, and colleagues Dr. Celeste G. Engel and graduate students Timothy H. Dixon and Robert J. Stern, are in their fourth year. They now know that over 10^6 km^2 of the region on either side of the Red Sea was an ocean-arc some 800 million years ago. This ocean arc with an exotic array of ultramafic and mafic rocks, sedimentary iron formations, and andesitic to dacitic volcanoes was collapsed and enveloped by granitic intrusions between 550 and 750 million years ago.



Graphical plot shows increasing fractionation and enrichment of K, Rb, Ba, and Zr in successively younger igneous suites in the Afro-Arabian crust. Note vertical coordinate is two cycle log.

The increasing degree of fractionation of the successively emplaced igneous suites are indicated from average concentrations of K, Ba, Zr, and Rb. All igneous rocks have extremely low initial Sr^{87} values suggestive of mantle origin. Both field and analytical data indicate Afro-Arabia evolved from ocean-arc to continental crust in some 250 to 300 million years.

In another area, the design and fabrication of the MANOP Bottom Lander, a free-vehicle system to carry out in situ studies of chemical and biological processes at the sediment-water interface and their relationship to the formation of ferromanganese nodules, have moved closer to scientific deployment in the North Pacific in 1980. This work is being carried out under the direction of Dr. Ray F. Weiss as a central part of the National Science Foundation-sponsored Manganese Nodule Program (MANOP). When completed, the bottom lander will operate as a remote station on the sea floor for periods up to one year and will carry out various chemical and isotopic tracer experiments and collect samples of seawater, sediment, and nodules.

Scientists in Dr. Weiss's laboratory have also continued research on trace gases. Continuous underway measurements of nitrous oxide, carbon dioxide, and methane in marine air and in surface ocean water were carried out aboard R/V *Melville* during three legs of Indomed Expedition, which extended from Bermuda to Montevideo, Uruguay, and from the Strait of Magellan to Manzanillo, Mexico. These measurements have provided valuable data for use in global modeling calculations and for the study of vertical mixing

Dr. Miriam Kastner (right) and graduate student Rachel M. Haymon (left) remove minerals from a sample of hydrothermal sulfide deposits recovered during the RISE Program.

Cross-section of a small, typical chimney spire. Discrete concentric zonations of sphalerite, pyrite, and chalcopyrite indicates episodes in the chemical and physical properties of the vents.

R. M. HAYMON AND DR. J. D. MACDOUGALL

processes in near surface waters. This work has also led to the development of a new gas-chromatographic method for the very high precision measurement of carbon dioxide in small samples—instrumentation that promises to be of great value in studies of the global carbon cycle and the fate of carbon dioxide produced by combustion of fossil fuels.

Marine Biology Research Division

The objective of investigations in the Marine Biology Research Division 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. The studies embrace experimental and descriptive biological disciplines, including physiology, biochemistry, microbiology, developmental and systematic biology, and ecology of the sea. Many are comparative in nature, and structures, events, or processes are examined in a wide range of marine and terrestrial organisms.

This year Dr. Robert R. Hessler participated in a multidisciplinary investigation of the animal communities at the Galápagos Rift hydrothermal vents. His responsibility is the documentation of the megafaunal component. Diving to a depth of 2,500 m the submersible *Alvin*, operated by Woods Hole Oceanographic Institution, Massachusetts, enabled direct observation, survey photography, and collection of voucher specimens. The vent fauna is extraordinarily unusual by deep-sea standards, being dominated by giant vestimentiferan worms, vesicomyan clams, mussels, serpulid worms, limpets, crabs, enteropneusts, and a strange benthic siphonophore. The excitement of these findings has subsequently been enhanced by the discovery of similar faunas at vents on the East Pacific Rise and the southern California continental borderland.

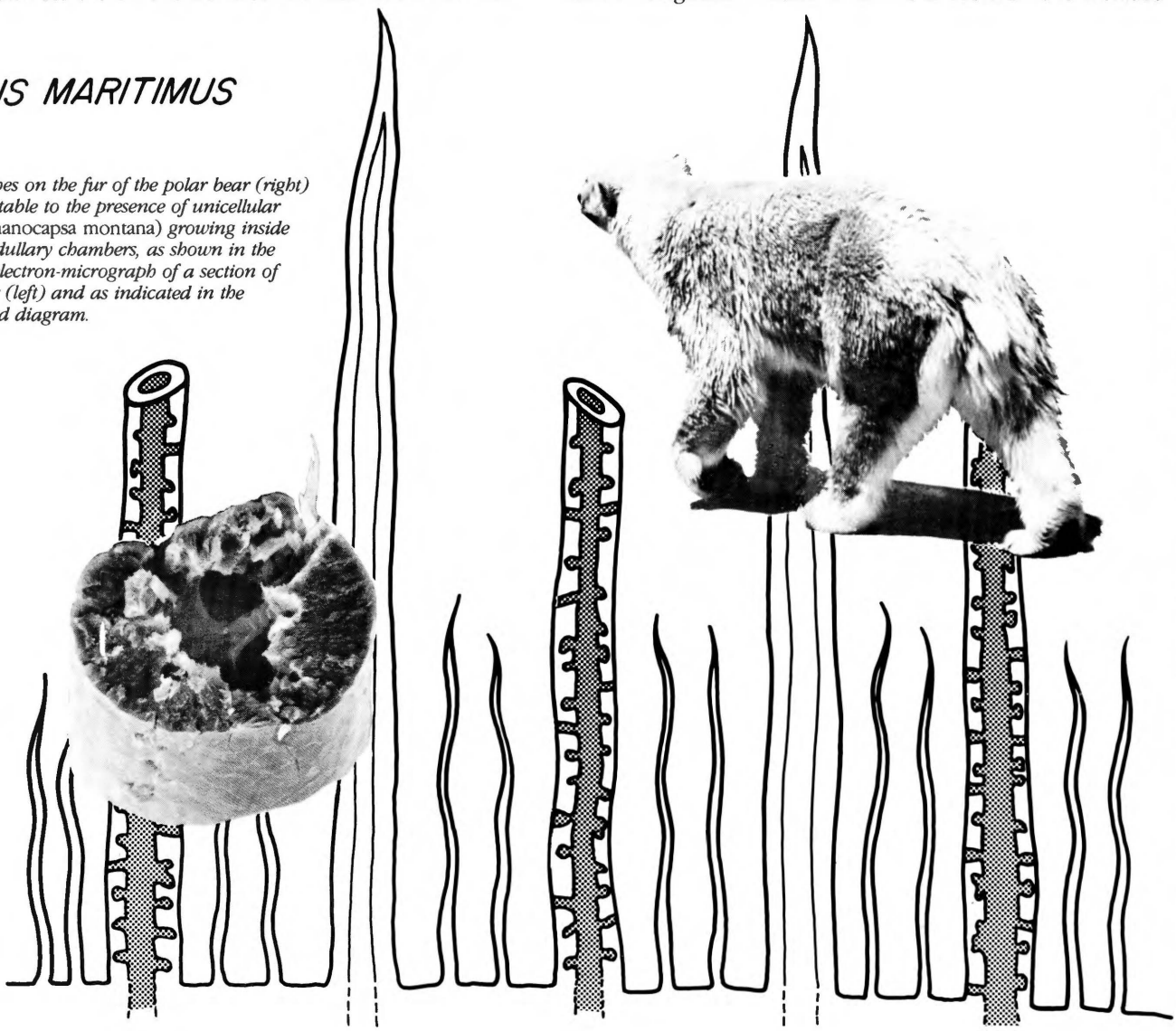
In another study, Dr. Nicholas D. Holland has described the formation of the egg envelopes that follows fertilization of the eggs of brittle stars. By electron microscopy, the fertilization membrane and the hyaline layer of the brittle star are much like those of the better known sea urchins and not at all like those of starfish. This finding helps support the theory that brittle stars are more closely related to sea urchins than to starfish. Another fine-structural study demonstrated that many European echinoderms harbor one or two morphological types of bacteria between the cuticle and the epidermal cells. These subcuticular bacteria are widespread, specific, and, apparently, nonpathologic. Depending on the echinoderm species, the bacteria may be spindle-shaped, spiral, bacilliform, or encapsulated rods.

On a different project, Dr. Ralph A. Lewin has now found *Prochloron* (assigned to a new algal subclass, the Prochlorophyta) symbiotically associated with didemnid ascidians not only on various tropical Pacific shores, but also on the coasts of Puerto Rico and St. Croix in the West Indies. He is extending collaborative studies of the peculiar biochemistry and physiology of this unique photosynthetic prokaryote. In collaboration with Dr. Phillip T. Robinson, San Diego Zoological Society, Dr. Lewin is also investigating the unicellular blue-green alga that sometimes causes polar bears to turn green in summertime. Dr. Nancy W. Withers continues to study pigments and lipids of symbiotic algae in various marine invertebrates; Dr. Karen Van Winkle-Swift is investigating the mating behavior and genetics of a homothallic unicellular green alga, *Chlamydomonas monoica*; and graduate student Robert A. Chastain is pursuing studies on the physiological relationships between nutrient depletion and the production of extracellular polysaccharides by certain green and blue-green algae.

Marine microbiology studies are still the focus of research in Dr. Kenneth H. Nealson's laboratory. In the past year the research has been on two groups of bacteria; those that emit light and those that oxidize manganese. Studies of luminous bacteria have included

URSUS MARITIMUS

Dark patches on the fur of the polar bear (right) are attributable to the presence of unicellular algae (Aphanocapsa montana) *growing inside hollow medullary chambers, as shown in the steroscan electron-micrograph of a section of guard hair (left) and as indicated in the background diagram.*



DR. P. T. ROBINSON—SAN DIEGO ZOOLOGICAL SOCIETY/POLAR BEAR, F. J. CROWE—DR. R. A. LEWIN/DRAWING, DR. L. CHENG/STEROSCAN

symbiosis, physiology, biochemistry, and genetics. Examinations of manganese oxidizing bacteria have included structural, physiological, and biochemical studies, as well as field studies to determine in situ activities.

In a different field significant progress was made in unravelling the complex speciation that has occurred in the eastern Pacific in the intertidal barnacle *Chthamalus*, during a workshop held by Dr. William A. Newman and colleagues. Four species and their respective ranges are now known where there was previously thought to be one between Baja California and Panama. The highlight of the year was the recovery of the first barnacle from a hydrothermal spring in 2,600 m of water by RISE Program scientists. It is a new genus whose morphology has been inferred to have evolved in the late Mesozoic and subsequently found refuge in the hydrothermal environment.

Research on the biochemical genetics of new world marine tropical fishes has continued in the laboratory of Dr. Richard H. Rosenblatt. A paper has been submitted with graduate student John E. Graves that demonstrates ten supposed species of hamlets actually represent color polymorphs.

Dr. Kenneth L. Smith, Jr., pursued several aspects of deep-sea research. Sediment community respiration and nutrient exchange rates were measured in situ at two stations in the central North Pacific and were found to be comparable to those measured in the oligotrophic western North Atlantic.

Dr. Smith has also studied the influence of food supply on mussel populations associated with the geothermal vents of the Galápagos Rift. Preliminary results suggest that the mussel populations inhabiting food rich areas immediately adjacent to the vents are in better physiological condition (for example, higher food reserves [fats and glycogen] and lower metabolic rates) than mussels inhabiting food poor areas some distance from the vents. The importance of food in influencing distribution of mussels in this environment is indicated.

Investigations in Dr. George N. Somero's laboratory focused on protein and solute adaptations of marine organisms. The work of Dr. Joseph F. Siebenaller, State University of New York, Stony Brook, provided evidence that enzymic adaptations may contribute to the establishment of depth zonation patterns in the oceans. Studies of Drs. R. David Bowlus and Paul H. Yancey revealed the bases for selection of solutes to be used in achieving osmotic balance in marine invertebrates and elasmobranch fishes. Dr. Yancey's work showed that marine elasmobranchs accumulate high concentrations of methylamine solutes that are able to counteract the effects of urea, which these species also contain at high levels, on protein structure and function. These urea antagonists may have clinical importance.

Dr. Joan G. Stewart has found in her studies that certain very distinctive aspects of meiocyte growth and meiosis in the staminate flowers of *Phyllospadix torreyi*, a marine monocot. The intertidal algae that grow above the *Phyllospadix*-dominated habitats form assemblages that are quite dissimilar at several study sites; possible causes of this differentiation are being considered with comparative field data and laboratory experiments.

During the year, scientists in the laboratory of Dr. Victor D. Vacquier have developed culture techniques that keep the sea urchin, *Lytechinus pictus*, continuously with gametes. Studies of the proteins mediating adhesion of sperm to eggs include development of a method to radioactively label the sperm surface proteins and lipids and follow their fate in the zygote and throughout embryonic development. Their new technique for isolating the cortex of marine invertebrate eggs has resulted in the determina-

DR. P. DUSTAN

Spectroradiometer and quantum scalar irradiance meter on Dancing Lady Reef in Discovery Bay, Jamaica.

tion that the major protein of the cortex is actin and it undergoes dramatic changes in stability at fertilization. A protein of 68,000 mol. wt. appears on the cortex when the cells commence prophase. A study of sperm-egg interaction in the abalone is being initiated.

The biological role of silicon continues to be the focus of Dr. Benjamin E. Volcani's laboratory. Dr. Pinakilal Bhattacharyya found that in intact cells, spheroplasts, and isolated membrane vesicles of the diatom, *Nitzschia alba*, silicate is apparently co-transported with Na^+, and a model involving membrane-bound Na^+, K^+-ATPase is being tested; a silicate-ionophore was isolated that may be a component of the transport carrier(s). Christopher Reeves, a UC San Diego graduate student, is investigating the participation of silicon in mRNA regulation and DNA synthesis. UC San Diego student Andrew Russo and Reeves characterized the cAMP and cGMP phosphodiesterases of *Cylindrotheca fusiformis*. In collaboration with Dr. Morris Kates, University of Ottawa, Canada, four novel sulfolipids found in *N. alba* were isolated, identified, and their probable biosynthetic pathways investigated.

In another laboratory Dr. Claude E. ZoBell and Jean S. ZoBell have continued to investigate the microbial release of oil from sedimentary materials both on the sea floor and in spent oil fields (ancient marine sedmients). Particular attention has been devoted to the microbial formation of surface-active substances or detergents, which tend to liberate films of oil. Dr. ZoBell has been trying to answer questions concerning the ways in which various microbial activities influence the safe storage of radioactive wastes. Most obvious is the microbial corrosion or degradation of certain containers of radioactive wastes, such as steel, concrete, and asphalt.

In a salmon study Dr. Andrew A. Benson is using spawning Pacific salmon as models for degenerative processes in humans. The site of action of the calcium-regulating hormone, calcitonin, and a unique model for sickle-cell disease were discovered by Dr. Gérard G. Milhaud, University of Paris, France, and Dr. Grant R. Bartlett, Laboratory of Comparative Biochemistry, San Diego. The mucus produced by fishes and by corals has been purified by Dr. James A. Christiansen and antibodies prepared for specific and sensitive assay of such mucus ingested by mucous-feeder fishes. Oceanic arsenic is converted by marine algae to phosphatidyltrimethylarsoniumlactate in order to avoid hazardous accumulation of toxic forms of arsenic. This membrane phospholipid, identified by Dr. Benson and associates, is relatively innocuous and responsible for the arsenic that occurs in many marine foods.

Dr. Theodore Enns has extended his studies of CO_2 diffusion in dog lungs to dog leg muscle. The new data show that, as in lung tissue, muscle tissue CO_2 diffusion is facilitated by bicarbonate ions when there is carbonic anhydrase in the cells. Quantitative data have been developed, so that CO_2 transport from muscle tissue to blood and blood to lung gas can be evaluated. In another area, a study of possible carbonic anhydrase activity in ocean water has been initiated. Preliminary data from a variety of ocean water samples show no evidence of such activity, contrary to current views.

Dr. Denis L. Fox continued his researches and writing on carotenoid fractionation in the plumose anemone, *Metridium*.

In the laboratory of Dr. Francis T. Haxo interest continues to focus on adaptations of the photosynthetic pigment systems of algae to the color and intensity of irradiance during growth. Dr. Phillip Dustan and Charles R. Booth have developed a small solid state spectroradiometer to determine spectral irradiance as well as integrated quantum level fluxes below the sea surface. The photosynthetic pigment composition and photosynthetic capability of freshly isolated zooxanthellae of the reef coral *Monastrea annularis* vary with in situ illumination over the depth range of the species. A model for photoadaptation in coral zooxanthellae is being evolved from these studies and those on laboratory cultured organisms.

Erratum: 1978 SIO Annual Report, page 9, paragraphs 4, 5, 6, & 7 should have been included with Dr. Benjamin E. Volcani's laboratory activities section on page 10, paragraph 8.

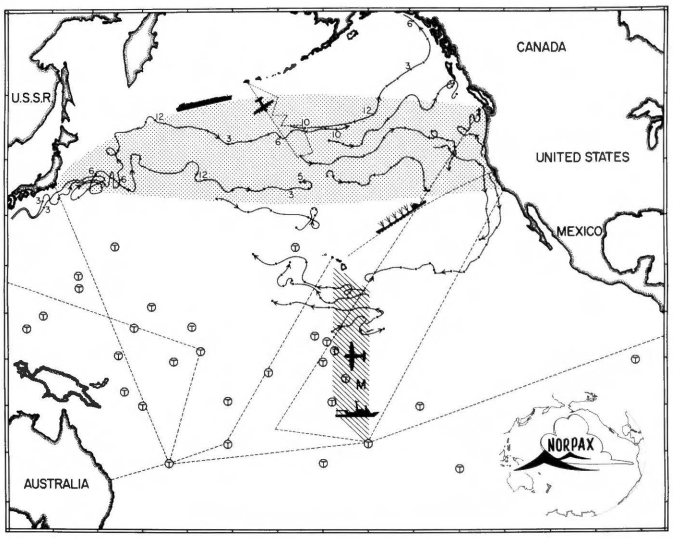
Ocean Research Division

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, marine chemistry, physical oceanography, and climatology.

The North Pacific Experiment (NORPAX) is a multiinstitutional study of the interaction between the ocean and the atmosphere on time scales of weeks to years and space scales of hundreds to thousands of kilometers. NORPAX is aimed at the long-term goals of prediction of the temperature structure of the upper ocean and use of ocean temperature as a tool for forecasting short-term atmospheric climatic changes. The NORPAX program presently involves 13 institutions and government laboratories, working in cooperation with Scripps scientists.

The locations of some of the NORPAX ocean observing systems now in place and operating are shown in the accompanying figure. Also shown by dashed lines are representative trajectories of satellite tracked drifting buoys deployed by Gerard J. McNally and Dr. William C. Patzert, and Dr. Dennis A. Kirwan, Texas A&M University, College Station. The trajectories have been smoothed to eliminate some of the small-scale variability. Each dash is the distance a drifting buoy was carried by the ocean currents during a month.

The broad band across the mid-latitude North Pacific is the TRANSPAC operating area. Drs. Warren B. White and Robert L. Bernstein have developed a program whereby XBT's (expendable bathythermographs) are deployed on a voluntary basis by the crews of 25-30 trans-Pacific commercial freighters. These XBT's measure the temperature profiles with depth in the upper 500 m of ocean. Since 1976 TRANSPAC has been building a unique picture of the month-to-month as well as year-to-year variability in the upper ocean thermal structure over the mid-latitude North Pacific. Results from this program indicate that the response of the ocean thermal structure to fluctuations in the westerly wind system is different than was previously thought. This indicates that ocean general circulation theory may have to be modified to account for these new measurements.



NORPAX

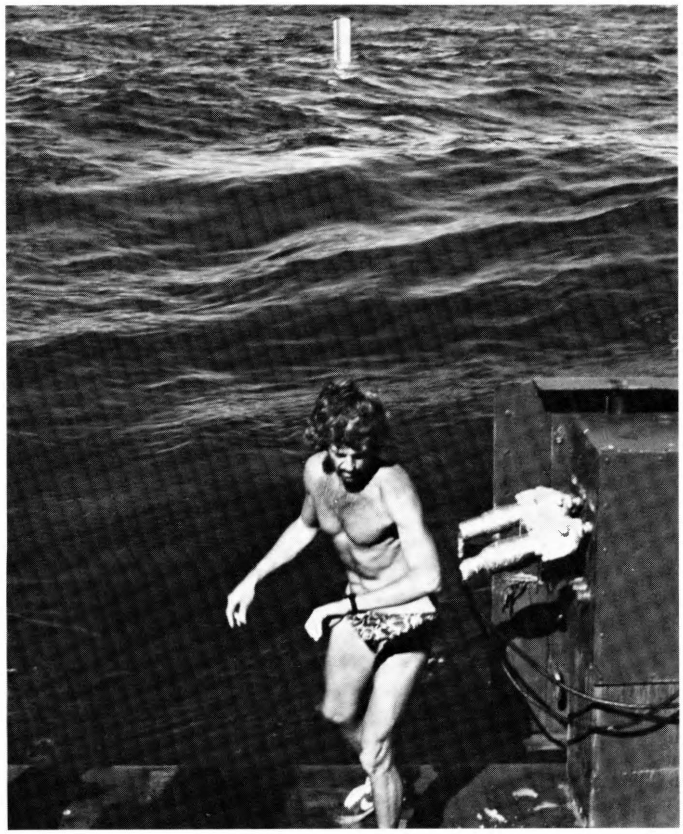
Shown are some of the NORPAX observation systems in the north and tropical Pacific. Stippled pattern at top is the TRANSPAC ship-of-opportunity XBT area; aircraft out of the Aleutians drop AXBTs along indicated course; wiggly lines are tracks of drifting buoys; dashed lines at lower latitudes are other ship-of-opportunity XBT tracks; Ts are special NORPAX tide gauges; aircraft and research ships operate in shuttle mode in cross hatched zone between Hawaii and Tahiti.

In order to learn more about the mechanisms connecting the oceanic climate changes in the western tropical Pacific to that in the eastern tropical Pacific, NORPAX has initiated an intensive, 16-

month field experiment to observe the ocean and atmosphere in the area between Hawaii and Tahiti.

Major components of this field experiment involve research vessels and U.S. Navy aircraft that shuttle back and forth from Hawaii to Tahiti. A research vessel makes one Hawaii-Tahiti-Hawaii round trip every two months. Onboard this vessel Scripps scientists are performing a variety of measurements that range from the primary physical oceanography and meteorology programs to geochemistry, biology, and geophysics. High precision, salinity, temperature, and oxygen profiles of the upper ocean are collected every 1° or ½° along the cruise track. Drs. Lloyd A. Regier, Russ E. Davis, Robert A. Knox, and David L. Cutchin are using the shuttle vessel as a test bed for an advanced acoustic current sensing system that may be capable of continuously recording the current profiles down to 150 to 200 m even while the ship is under way. Dr. Patzert and McNally are periodically deploying arrays of satellite tracked drifting buoys to follow the surface current patterns over a larger area than can be sampled with the ship. Dr. Knox, in cooperation with Dr. David Halpern, National Oceanic and Atmospheric Administration, are maintaining a small 1°x1° array of moored current meters at the junction of the equator and the 153°W meridian. This array will provide a continuous time series of currents and temperatures at five discrete depths between 15 m and 200 m. The surface buoys for these moored current meter strings carry vector averaging anemometers to record the surface wind.

Analysis of the tropical Pacific pilot experiment data indicates that large-scale coherent variability exists in the region within ±10° of the equator. The time scale associated with this variation is of order two to three months. At 150°W, the large-scale variability generally extends coherently across the equator, the boundaries between major equator currents, and the intertropical convergence zone. Comparisons between velocity/transport derived from temperature/salinity relations and actual current meter observations in the North Equatorial Countercurrent indicate that the variability of the upper ocean temperature field also applies to the velocity field.



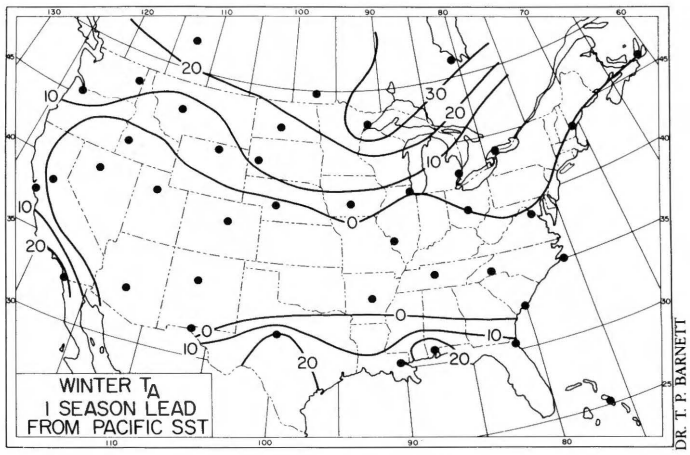
NORPAX

Dr. William C. Patzert launches a satellite tracked drifting buoy near the equator in the Central Pacific Ocean during a Hawaii/Tahiti shuttle experiment.

In the Climate Research Group, under the direction of Dr. Jerome Namias, a study of recent, 1976-1977, drought conditions in the western United States has been completed. In 1976 observed anomalous atmospheric warming of 3°-4°C from the surface to 10 km in the core of the drought area and diminishing relative humidity in the lower troposphere can be accounted for by subsidence of the order of several hundred meters per day. During winter, extremely strong high-latitude westerlies and strong subtropical high-pressure systems extended into western areas of the United States and western Europe. Newly derived seasonal teleconnections suggest that anomalous ageostropic banking to the right of the high-latitude westerlies, reinforced by sea-surface temperature (SST) gradients, created the anomalous winter subtropical anticyclones.

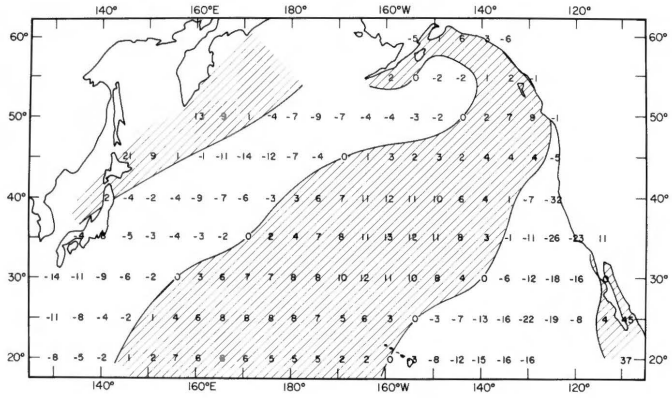
In Dr. Namias's group, Dr. John O. Roads has completed two sets of experiments on the atmospheric effects of SST anomalies in his simplified atmospheric general circulation model. The first experiment showed that anomalous air/sea heat exchange at low (0°-23°) and high (47°-70°) latitudes is more important in determining the structure of the stationary eddies in mid-latitudes than a comparable oceanic heat flux in mid-latitudes. This is mainly because of the high propagation velocities of Rossby waves at mid-latitude and subsequently smaller ocean/atmospheric interaction time. The other modeling effort showed that fluctuations in snow albedo have a positive feedback to the climate system, by engendering additional snowfall, and decreased the surface temperature on the continent.

A study of the predictability of seasonal air temperature over the United States using Pacific SST and sea-level pressure predictors for both mid-latitude and tropics has been completed by Dr. Tim P. Barnett. The study showed that significant predictability exists along the eastern and western coasts of North America in all seasons except summer. During the winter season predictive skill was found again along the coasts and across the northern tier of states. The study verifies the hypothesis that sea-surface temperature can be used to predict climate fluctuations over North America. The main predictability comes from water temperature anomalies in the tropical Pacific. This indicates that perturbations in the momentum and heat flux from this area play a first order role in mid-latitude climatic fluctuations as hypothesized some years ago by Bjerknes. The predictability studies also show that exceptionally large tropical perturbations are associated with climate perturbations over most of North America. These large fluctuations have an average recurrence time of 4-5 years.



Contours show the percentage of winter air temperature variance captured by the hindcast model. Dots indicate hindcast station positions.

Apart from the NORPAX related studies, many investigations are being conducted on an individual and group basis. Dr. Kern E. Kenyon has continued to analyze deep hydrographic data along 35°N between California and Japan and made a new analysis of North Pacific surface temperature. Dr. Kenyon's spatial anomaly



DR. K. KENYON

Spatial anomaly of sea-surface temperature for the North Pacific for the month of August. Residual temperature values in °Cx10.

map for August is shown in the accompanying figure. It is based on twenty-year mean data, in which the large-scale poleward and eastward temperature gradients have been removed. The large shaded band of positive temperature anomaly, which is a permanent feature, is interpreted to be the surface expression of a shallow poleward and eastward current. This current is caused by the large-scale poleward temperature gradient and is part of a circulation that transports heat and eastward angular momentum poleward as is required of the ocean.

Dr. Jason H. Middleton, in collaboration with Dr. Theodore D. Foster, UC Santa Cruz, continued the analysis of data obtained during expeditions to the Weddell Sea, Antarctica, in 1976 and 1978. The 1976 data indicate that Antarctic Bottom Water (AABW) formation is seasonally dependent, but also varies from year to year. In the northwestern Weddell Sea, water masses lighter than AABW appear to flow down the continental shelf and interleave with circumpolar water at intermediate depths rather than flowing completely to the bottom as AABW.

Dr. Jean H. Filloux and his group completed an intense field work program of open ocean magnetotelluric and sea-floor pressure fluctuation observations. Excellent data have been obtained in the vicinity of the Hawaiian Island chain, in the Marianas, and in two areas of the East Pacific Rise.

In Dr. Joris M. Gieskes' laboratory, activity was concentrated on the study of Deep Sea Drilling Project (DSDP) sediments. Dr. Russell E. McDuff completed his work on the conservative behavior of calcium and magnesium in interstitial waters of DSDP cores. Dr. Gieskes participated in Leg 64 on D/V *Glomar Challenger* in the Gulf of California. Particularly interesting are the results in the Guaymas Basin, where effects of hot basaltic intrusions into wet sediments are evident from large increases in dissolved lithium, potassium, and rubidium in interstitial waters. These results are of great interest with respect to the current high interest in basalt-seawater interaction.

In this same laboratory graduate student Gerald S. Wirth is nearing completion of his research on the dissolution kinetics of amorphous silica. Alan Shiller started work on trace metal analyses, using polarographic techniques, and he has developed methods for the study of particulate matter in the ocean.

The GEOSECS (Geochemical Ocean Section Study) Operations Group and the Data Collection and Processing Group have merged and now operate as the Physical and Chemical Oceanographic Data Facility (PACODF).

The seagoing phase of GEOSECS was completed with the recent intercalibration work at the location of, and ten years after, the original GEOSECS test station, approximately 300 km west of Guadalupe Island. A total of 66 casts were made collecting samples for shore-based measurements of ^{14}C, ^{3}H, ^{39}Ar, ^{3}He, ^{4}He, ^{228}Ra, ^{226}Ra, ^{210}Pb, ^{18}O, Ba, and pCO_2, as well as shipboard measurements of ^{222}Rn, N_2O, CO_2, alkalinity and total CO_2, nutrients, dissolved oxygen, and salinity. The analyses of geochemical samples from the Indian Ocean Expedition and the preparation of the GEOSECS Atlas series are currently in progress.

During the last year personnel from PACODF participated in two legs of the continuing Indomed Expedition and the group is currently heavily involved in the NORPAX tropical Pacific field experiment between Hawaii and Tahiti. PACODF is providing hydrographic support to the project, as well as nutrient analyses and the extraction of radiocarbon samples from surface seawater.

PACODF has been participating in the planning phases of a large program concerned with both the documentation of the transient signal produced in the ocean by atmospheric testing of nuclear devices and the role of the ocean as a sink for carbon dioxide produced from the combustion of fossil fuels. This program, Transient Tracers in the Ocean, is tentatively scheduled to begin with a pilot cruise in the North Atlantic in 1980, followed by a major North Atlantic expedition of about six months duration in 1981.

Dr. Tsaihwa J. Chow and graduate students Robert J. Stern and Timothy H. Dixon studied the abundances of K, Rb, Sr, and Ba in volcanic lavas from the northern Mariana Island arc. While Sr is relatively constant, K, Rb, and Ba covary strongly with silica. The variation of elemental ratios of the Mariana lavas suggested that it is unlikely that the intra-oceanic arcs of the circum-Pacific can be characterized by a single mean value. Ranges of elemental ratios among different island arc lavas are distinctive, but with some overlap.

Dr. Chow and John L. Earl completed the study of trace metal distributions in southern California coastal sediments; they also surveyed trace elements in petroleum crudes to gain an understanding of the biogeochemistry of oil deposits and to develop possible tracers for identifying petroleum of various localities.

In atmospheric chemistry several new activities are under the direction of Dr. Ralph J. Cicerone. Both theoretical and experimental studies are focused on trace gases in the lower and upper atmosphere, especially those that control atmospheric photochemistry and can influence global climate through their radiative properties. Dr. Cicerone's theoretical studies include computer modeling of the photochemical kinetics of the stratospheric ozone layer and how natural processes and human activities affect it. A particularly interesting group of gases that is being measured by gas chromatographic methods is that with mostly biospheric sources: methane, nitrous oxide, and certain sulfur gases.

At the Mt. Soledad Radioisotope Laboratory, Dr. Robert C. Finkel has been using uranium-thorium series and cosmogenic radioisotopes as geochemical tracers in a number of investigations: earthquake prediction techniques, the marine chemical cycle of trace elements, bioturbation of deep-sea sediments, the chronology of recent volcanic activity, and the history of the polar ice caps.

For the earthquake precursor study, uranium concentrations and $^{234}U/^{238}U$ isotope ratios are routinely monitored in water from 14 southern California hot springs and wells. The activity ratios proved to be remarkably constant, thus simplifying the detection of any possible earthquake precursory signal. No earthquakes have occurred close enough to the monitoring sites to properly test the hypothesis.

In a totally different field, ^{210}Pb measurements in deep-sea carbonate sediments are showing that the upper 5-10 cm of the sediment column are being actively reworked by benthic organisms. Investigations are under way to explore the parameters that control the observed bioturbation rates and the manner in which bioturbation affects the chemistry of the sediment pile.

During the past year Dr. Theodore R. Folsom has reviewed and published records of more than 3,000 measurements made between 1954 and 1974 of effects of historical global fallout on the Pacific Ocean and on some of its living organisms. By using several simple mathematical models, some interpretations of this data have been made so as to suggest the rates at which the surface waters just west of California have purged themselves of seven chemically different nuclear wastes. These include fallout nuclides that had been monitored in surface seawater samples and also in tissues of North Pacific albacore for more than ten years. This study has suggested that background conditions of these nuclear wastes were influenced mostly by advection of fallout by surface currents from the far northwestern Pacific with relatively little downward

loss. The advection rates derived from fallout concentration changes were not inconsistent with geostrophic predictions.

Scientists at the Mt. Soledad Tritium Laboratory have been engaged in Antarctic research for the past year. The circulation of water under the Ross Ice Shelf was investigated by the use of both tritium and carbon-14. The renewal of water under the Ross Ice Shelf was found to be rapid (< six years) in the upper layers of water at the ice hole, but deeper waters and water flowing out under the ice shelf on the west side of McMurdo Sound were significantly older. Measurements of tritium distributions in the Weddell Sea show the highest levels of bomb tritium are found near the continental shelf break where Weddell Sea Bottom Water (WSBW) is thought to form. The formation rate of WSBW was calculated to be 3.5×10^8 m^3/sec, which corresponds to a formation rate of classical Antarctic Bottom Water of 7×10^8 m^3/sec.

Dr. Paul K. Dayton's nearshore ecology group has completed several studies this year, which included the projects of the following graduate students. Timothy Gerrodette worked on population dynamics and dispersal of cup corals, John S. Oliver studied the organization of soft bottom communities, and Frederic C. Gunnill worked on population biology and distribution patterns of the fauna associated with intertidal algae. Ongoing projects include the kelp research by Janice E. Thompson on sponge defense mechanism and by Lisa A. Levin on dispersal of back-bay polychaetes.

Dr. Mia J. Tegner's group continued studies of sea urchin population dynamics and the role these echinoderms play in structuring southern California kelp-bed communities. The project's long-term goal is to develop a multispecies approach to the management of kelp-bed resources. Experiments have shown that spiny lobsters and California sheephead are the only predators of adult red urchins. Exploitation of these species, as well as abalones that share the urchins' food and habitat resources, is thus likely to be a major cause of episodes of sea urchins destructively overgrazing kelp beds in recent years. Joint cruises with California Department of Fish and Game biologists have examined the impact of the urchin fishery on Channel Island urchin populations off California.

Investigations of the geochronological, biological, and archeological applications of amino acid racemization and decomposition reactions are being continued by Dr. Jeffrey L. Bada and coworkers. 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 continues to investigate the effects of amino acid racemization on protein structure and function during the biological aging process in humans and other mammals, by use of ocular lens proteins as a model system. Of particular interest is the association between accelerated aspartic acid racemization and one type of human cataract. In addition she has begun racemization kinetics studies of processed food proteins. Significant amounts of D-aspartic acid can be found in commercial food products containing these processed proteins. D-amino acids are not readily metabolized and some are known to be toxic to experimental animals. Work is also continuing on racemization dating and paleotemperature estimates for southern California coastal indian sites; Little Salt Spring, Florida; and Neanderthal sites in the eastern Mediterranean.

Dr. Daniel Goodman completed three demographic analyses that permit animal population prediction with incomplete information. One of these models helps identify the maximum yield point in a harvested population. The second allows calculation of the population growth rate given only the age distribution and mortality statistics for the adult age classes. This is far more readily applied than formulas requiring the entire age distribution and life table, for it is usually very difficult to obtain such information for very young organisms. The third model helps identify the population structure that minimizes the probability of extinction. This will be of use in maintaining small populations of endangered species. He also continued work on the analysis of repeated patterns in plankton and terrestrial vegetation.

The Shore Processes Study Group is investigating the physical and sedimentary processes in the nearshore environment. Basic to this study are field measurements leading to an accurate description of the fluid driving forces due to waves and currents, and the resulting sediment response. The staff and students conducted large-scale field experimental programs in the surf zone and on the continental shelf as their primary source of data.

Also in the Shore Processes Study Group, Drs. Douglas L. Inman, Robert T. Guza, Reinhard E. Flick, and James A. Bailard and graduate students participated in a multiinstitutional, large-scale, three dimensional field experiment of the ongoing Nearshore Sediment Transport Study (NSTS). The ultimate goal of the NSTS is to develop improved engineering relations to predict the rate of longshore sand transport given measurements of offshore waves and longshore current on the surf zone.

M. P. CLARK

Scientists take sediment samples in the surf zone off Torrey Pines Beach.

During the NSTS field experiment, 30 electromagnetic current meters and numerous wave staffs and pressure sensors were used to describe the offshore waves and the surf zone current structure. Dyed sand tracer total transport measurements were conducted for comparison with the driving force data. In addition, measurement of suspended sand concentration, dye circulation, beach profile, and overflight and time-lapse photography were taken to round out the environmental description of the measurement site. Data gathered are being archived and distributed through the National Oceanic Data Center.

The Shore Processes Study Group is also continuing its investigation of innovative sediment management techniques in lagoons and harbors. Under the sponsorship of the Naval Facilities Command (NAVFAC) the group has developed, installed, and monitored sedimentation control devices at Mare Island Naval Shipyard, Vallejo, California. These consist of a passive barrier curtain to seal off a finger pier berth and an active water-jet array to sweep sediment away from a quay wall. Both installations are effective and environmentally viable alternatives to expensive and disruptive conventional dredging methods used to remove fine sediment accumulations. Scientists on NAVFAC project are also investigating alternatives to sand dredging, a large expense in approach and access channels of many harbors.

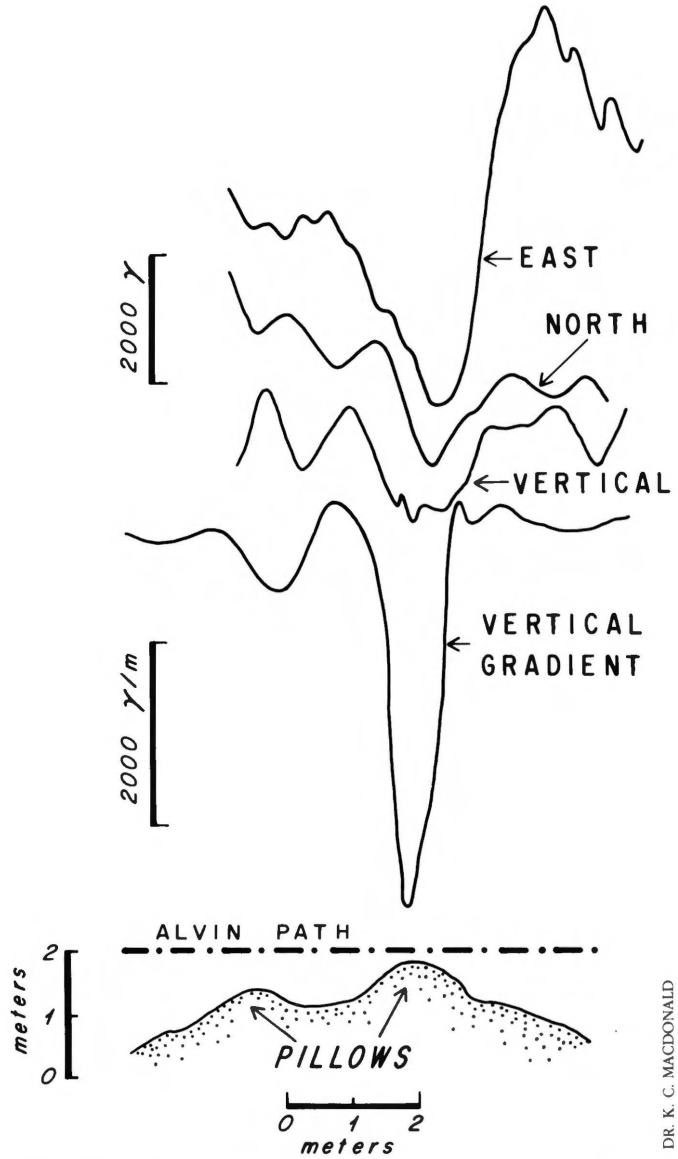
In this same group, Dr. Clinton D. Winant and graduate students have recently completed a study of seasonal variability of coastal currents over the southern California continental shelf. Their study used conventional, moored current-meter arrays and temperature sensors to describe the temporal fluctuations of currents and temperature, and they related these to seasonal and short-term meteorological forcing. Of particular interest were strong, episodic storm events with wind forcing from the south, off Mexico. These events, occurring mainly in the summer, trigger widespread downwelling along the southern California coast resulting in a buildup of warm coastal water.

Marine Physical Laboratory

Ocean acoustics, sea-floor studies, marine geophysics, and marine technology continue to be the principal areas of interest to the research groups at the Marine Physical Laboratory (MPL). Investigations have been conducted in the waters of the eastern Pacific, the Indian, and the eastern and western Atlantic oceans, involving ships of the Scripps research fleet, the research platforms FLIP and ORB, and submersibles *Alvin*, operated by Woods Hole Oceanographic Institution (WHOI), Massachusetts, and *Seacliff*, operated by U.S. Navy. The state-of-the-art in marine technology has been advanced in the areas of Doppler sonar, acoustic array design, data processing, and sea-floor navigation.

Deep Tow investigations began this year in the Red Sea aboard R/V *Melville* under cochief scientists Drs. Kenneth C. Macdonald and Peter F. Lonsdale. Major areas of study included the tectonic structure of the Red Sea deeps and brine pools and the origin and setting of the hot brines. Dr. Macdonald completed work on data acquired during Deep Tow surveys of the Gulf of California Tamayo transform fault and on a three-dimensional analysis of a magnetic reversal boundary.

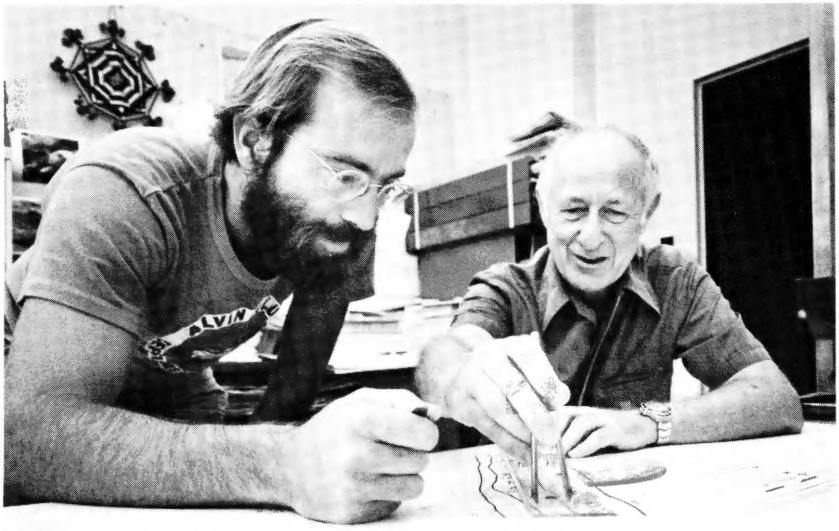
After the Red Sea operation Dr. Fred N. Spiess led a deep-tow expedition in the eastern Mediterranean, with Dr. William B. F. Ryan, Lamont-Doherty Geological Observatory, Palisades, New York. The goal was the delineation of the complex fine scale "cobblestone" topography characteristic of the region. Three sites were mapped in detail by using high-resolution, near-bottom sounding, 4-kHz bottom penetration system, and side-looking sonar. All showed relief characteristically in the range of 200 m, but with quite different styles in the three areas—ranging from rounded hills and hollows to very steep-walled, flat-floored valleys and plateaus. Long lived transponders were left to provide a base for carefully controlled bottom sampling on a subsequent cruise by R/V *Eastward*, operated by Duke University, Beaufort, North Carolina.



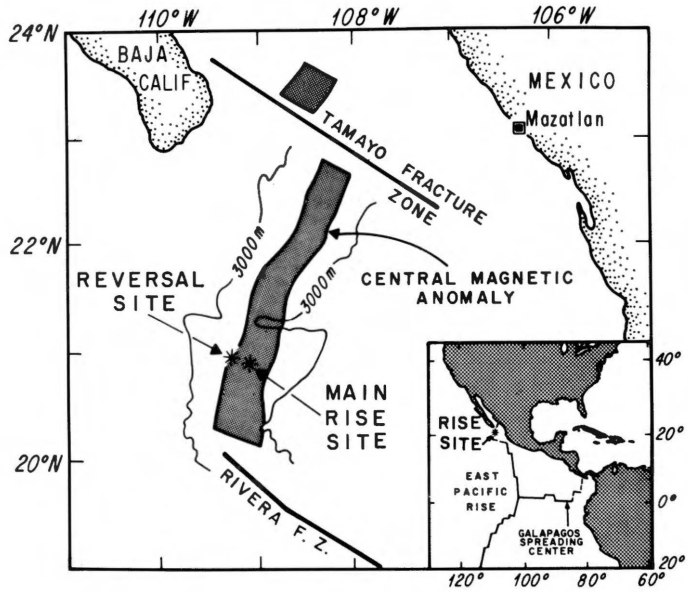
Alvin *magnetometer crossing of two negatively magnetized pillow basalts. Top three lines are the components of the field as noted, the bottom line is the vertical gradient. Over 250 clear measurements were made on either side of the polarity boundary, with all measurements showing the "correct" polarity. The boundary is very narrow implying a narrow zone of crustal formation.*

In the spring Dr. Macdonald was cochief scientist with Dr. Spiess on the RISE Program. This international (U.S.—France—Mexico) program involved various groups at Scripps. MPL's Deep Tow system and WHOI's ANGUS camera system were used in conjunction with *Alvin*. Highlights include one of the most spectacular oceanographic discoveries of the decade, active hydrothermal fields venting 400°C waters; some blackened by sulfide mineral precipitates.

During the RISE expedition scientists found that the axis of the East Pacific Rise is marked by a zone of recent volcanism approximately 1,000 m wide. Near the center of the volcanic zone, there is a very narrow band of active hydrothermal vents; at least 25 vents along a strip 7 km long and only 200-300 m wide. In the northeast, vents are characterized by water temperatures of 5°C to 20°C, flow rates of cm/sec, clear vent waters, and exotic biological communities similar to those at the Galápagos vents. These communities, independent of photosynthesis for survival, must have unusual dispersal systems allowing them to populate various areas of the world rift system as hydrothermal vents evolve and die out. To the southwest, vent waters contain more particulate matter, often dark in color "black smokers," the exit temperatures



Cochief scientists on the RISE Program, Dr. Kenneth C. Macdonald (left) and Dr. Fred N. Spiess discuss the width of the hydrothermal zone discovered during the RISE Program. Location of RISE Program research sites in relation to the East Pacific and Galápagos Spreading Center in the equatorial Pacific is shown at right.



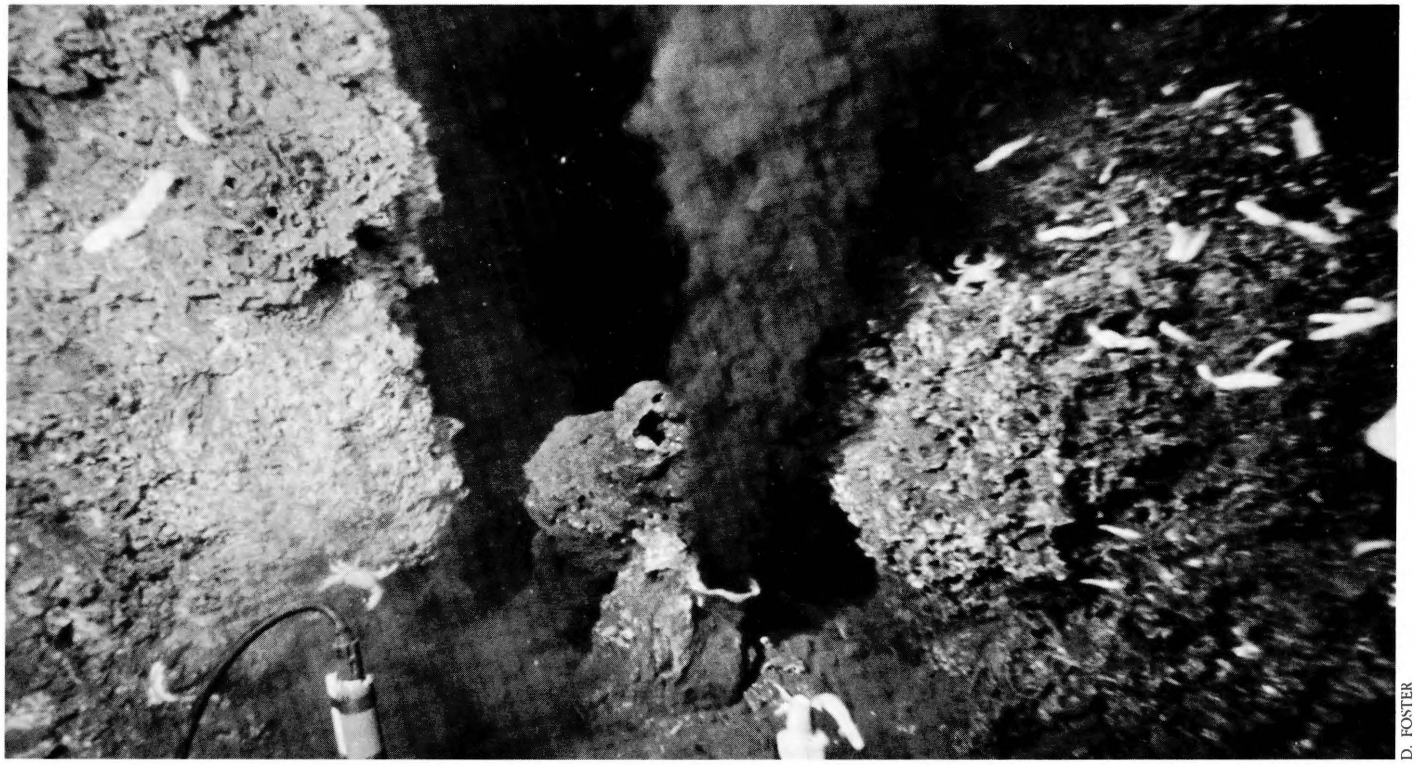
reach 400°C ± 10°C, flow rates are on the order of several meters per second, and conditions appear less inviting for the biological communities near the vents, except for a new polychaete that may live at very high temperatures. The marked along strike variation may indicate an evolutionary cycle in the development of the vent system. Actively forming massive sulfide deposits occur within the vent chimneys at high temperature springs, while inactive sulfide mound deposits occur slightly off-axis from the cooler vents. Mineral deposits include sphalerite, pyrite, chalcopyrite, (and other Fe, Cu, and Zn sulfides) anhydrite, sulfur, barite, opal, and talc. The chimneys exhibit a distinct concentric zoning of sulfide minerals that suggests episodicity in the physical/chemical properties of the vents. The hydrothermal waters contain the first such occurrences of pyrrhotite and other sulfide compounds as well as methane (CH_4). Covariance of CH_4 with ^3He indicates a mantle source for both. There is substantial evidence for biological influence on the mineral deposits; for example, worm-tube honeycomb structures form the foundations for many sulfide mounds.

Basalt samples from the spreading center have a narrow range of chemical composition and are extremely primitive. They have probably formed by fractional crystallization from a shallow magma chamber and possibly from a single parent magma.

Alvin has been used for the first time as a geophysical tool. The on-bottom gravity and seismic measurements have yielded the first in situ determinations of shallow crustal seismic velocity and density. Further analysis of the gravity, seismic, and electrical data, hopefully, will place bounds on the depth of hydrothermal activity and crustal fissuring, and will determine the nature of the extent of the axial magma chamber. Magnetic measurements at the reversal boundary indicate a narrow (500-1,000 m) zone of crustal formation, and may place bounds on the role of deep crustal sources in generating marine magnetic anomalies.

After participating in the Red Sea work with Dr. Macdonald, Dr. Lonsdale led a multiinstitutional cruise across the North Atlantic from Spain to Bermuda. Geologists and physical oceanographers gathered aboard R/V *Melville* to study four patches of ocean floor where bottom currents were shaping the relief by cutting erosional furrows or building depositional mud waves. Equipment used included the Deep Tow system, CTD's and hydrocasts, current meters, nephelometers, and corers. Unexpectedly fast and persistent bottom currents were found below 400 m at several sites, and sedimentary bedforms and the structure of the overlying benthic boundary layer were more thoroughly mapped than in previous studies.

Dr. Larry A. Mayer completed his investigations of internal reflectors in carbonate sediments. His work demonstrated that the well-defined internal reflectors, observed with the deep-tow, near-bottom 4-kHz system, were caused by constructive interference patterns generated by small variations of acoustic impedance that had a vertical scale comparable to the acoustic wavelength. Dr. Karen F. Wishner also completed her study of near-bottom deep-sea planktonic populations, based on net tows made using the



D. FOSTER

Active hydrothermal vent of the "black smoker" type. The 400° C water jets out at flow rates of 1-3 m/sec. blackened by sulfide precipitates.

deep-tow system in a variety of areas that ranged from the Red Sea to the equatorial Pacific.

The seismic group under Dr. George G. Shor, Jr., worked on two projects during four cruise legs on two ships on two different oceans. Work on measurements of the attenuation coefficient as a function of depth in thick sediments of deep-sea fans had been, in previous years, devoted to design and construction of a sea-floor hydrophone system. At present they are set to cover signals up to 80 Hz. The system was tested on two cruises on R/V *Ellen B. Scripps* to the Monterey Fan off central California and was given additional testing in conjunction with work in the Mariana Arc. In February, these instruments were deployed in 3,000 m deep water in the central part of the Bengal Fan from R/V *Thomas Washington*, where they were used to record signals from shots fired at depths of 1.8 and 2.4 km below the sea surface. Preliminary analysis of the data shows that at a depth of about 600 m beneath the sea floor the attenuation coefficient for sound drops abruptly to about 30% of its near-surface value, and it stays at that decreased level to depths as great as measured (about 2.2 km). On this same cruise multichannel seismic reflection work was carried out. Also observations of internal wave effects on the deep-scattering layer were made. Shallow-penetration studies of sediment erosion and deposition on the Sunda Shelf were also conducted.

Between the cruises devoted to attenuation work, the group joined in a major multiinstitutional program of investigation of the structure of the Mariana Arc to determine the nature of the accretionary wedge between the trench and the island arc, and the structure of the Mariana Trough west of the island arc. A tropical storm caused postponement of the work east of the arc. The program in the Mariana Trough was more successful; it resulted in detailed information on rock types and crustal structure within the trough. Measurement of detailed seismicity and (high) heat flow near the spreading center of the Mariana Trough was also made.

Victor Vacquier and graduate student Keir Becker along with U.S. Geological Survey scientists obtained 54 new heat-flow measurements in the Guaymas Basin, Gulf of California, during an International Phase of Ocean Drilling (IPOD) site survey. During subsequent drilling on Deep Sea Drilling Project (DSDP) Leg 64, thermal conductivity and paleomagnetic measurements were carried out by Vacquier. The heat flow in the DSDP holes confirmed the values obtained with surface gradient measurements during the IPOD site survey. Becker obtained many additional heat-flow measurements during three cruises to active spreading centers, in an attempt to determine the effects of hydrothermal circulation on regional heat budgets.

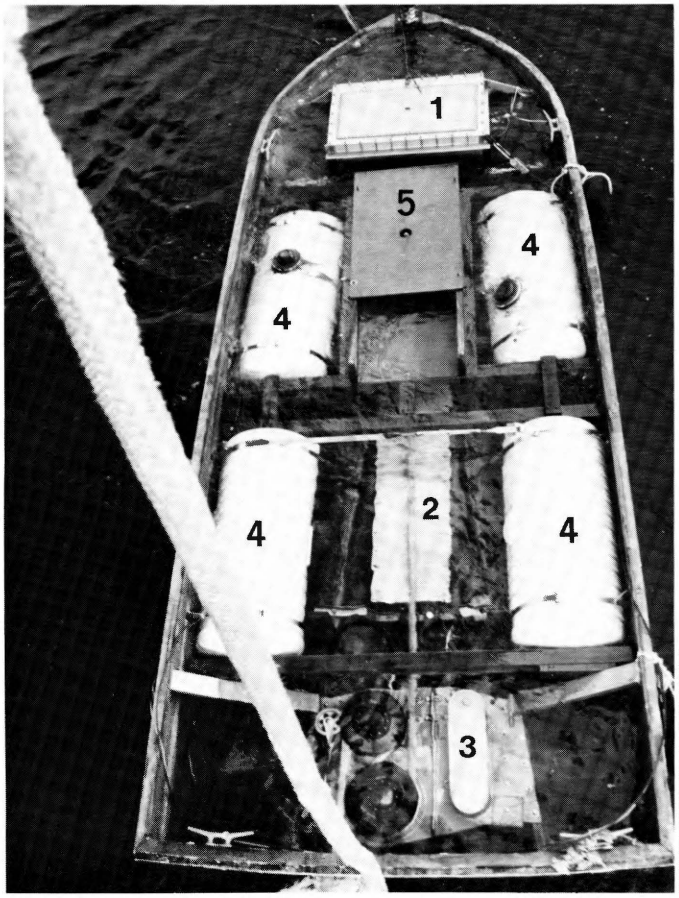
During March, FLIP was used in acoustics studies of the deep ocean west of San Diego. Dr. Robert C. Tyce used a vertical array of 20 hydrophones to study the directionality of ambient noise at low frequencies. The array was positioned at the same five depths utilized during a similar experiment with a longer array last year. This was done to extend the results of that experiment to higher frequencies (50-400 Hz), where the effects of storm generated noise begin to become important.

Dr. William S. Hodgkiss, Jr., worked with Dr. Tyce on the analysis of ambient ocean noise data collected on two previous FLIP expeditions, one of which concentrated on measurements of acoustic energy in the 10-50 Hz band, and the other in the 50-400 Hz band. The objectives of the analysis are to assess the vertical arrival structure, the fluctuations of ambient ocean noise power with time, and the statistical characteristics of the noise field observed by narrow beams.

Dr. Hodgkiss also investigated the capability of adaptive array processors to cancel (null) the surface reverberation return from an active acoustic pulse. Deterministic null steering is not applicable since the patch of sea surface causing the reverberation return is changing its range as the pulse propagates outward. Further complications involve the probable motion of the acoustic source with time.

The group directed by Dr. Tyce completed development and testing of a remotely controlled line crawler to aid in the vertical positioning of long horizontal arrays of sensors from FLIP. This work involved the powering of a ten horsepower motor over more than 4,000 m of RG58-type cable. The line crawler machinery, together with more than 2,200 kg of buoyancy, was built into a 6x2.4 m boat and tested from *Ellen B. Scripps* during April.

During May, Dr. Tyce used FLIP in engineering and acoustic studies, while moored among the Channel Islands off San Diego. The line crawler again was used to deploy a horizontal array of hydrophones to depths of more than 90 m. In addition, a vertical array and another horizontal array were deployed from FLIP for



MARINE PHYSICAL LABORATORY

Line crawler prior to descending on mooring line. Power and control are supplied through an armored coaxial cable not visible. 1) control electronics, 2) electrohydraulic converter (motor/pump), 3) traction unit/drive sheaves, 4) buoyancy modules, 5) hydraulic compensator.

acoustic studies. This second horizontal array was a special experimental Kevlar array with nine hydrophones. Measurements of ambient noise, ship noise, and special sound source signals, for array location experiments, were made on all three arrays.

Dr. Victor C. Anderson and Daniel K. Gibson fitted the unique submersible acoustic array ADA with newly designed hydrophones and an improved dome structure. It was tested in a deep water moor prior to its scheduled data collection operation in 4,500 m of water west of San Diego.

Analysis of acoustic data taken with a narrow-beam 87.5 kHz echo sounder on FLIP has revealed many interesting features of sound-scattering biota. Individual scatterer characteristics indicate that reverberation from below the mixed layer is the result of pelagic fishes or similar sized animals, half of whom were observed to migrate diurnally with the Deep Scattering Layer. Previous laboratory measurements have shown that animals such as squid or pelagic crabs, which have physical cross-sectional areas comparable to fish, have similar acoustic target strengths at high frequencies. In spite of the fact that these animals do swim, they collectively serve as water motion tracers for acoustic remote sensing of internal waves. A tracking algorithm was developed that could confidently recover internal wave information from the echo sounder data. Finally it was shown that the vertical distribution of these neutrally buoyant animals is not governed solely by the temperature gradients in the water column.

In the sound propagation research on multipaths and caustics, Dr. Frederick H. Fisher and Robert B. Williams developed methods to model the variability in the vertical arrival structure as a function of range environment. Frank M. Phelan improved the analysis system for reducing vertical arrival structure data by interfacing an HP 21 MXF computer with a CSPI—MAP 300 array processor.

In his ion-pairing research Dr. Fisher has proposed the weak electrolyte NH_4OH as a standard for dissociation constants since its pK can be deduced from acoustic, conductance, and density data with minimal dependence upon Debye-Hückel theory. Dr. Fisher and A. Peter Fox, in a paper on conductance in aqueous solutions of KCl up to 2,000 atm, show that currently accepted conductance theory (Fuoss/Hsia/Fernández-Prini) yields nonrandom errors that increase with pressure.

UC San Diego graduate student Cheng-chich Hsu worked with Dr. Fisher on measuring the reduction of sound absorption in $MgSO_4$ solutions when NaCl was added. From this reduction in absorption the amount of ion-pairing of $NaSO_4^-$ and $MgCl^+$ can be deduced. This work is complementary to earlier conductance measurements in Na_2SO_4 and $MgCl_2$ solutions. The acoustic measurements were made in a 100 liter titanium sphere used as an acoustic resonator. The Q of the resonator is very high; the highest value of 100,000 being found at 25 kHz.

Dr. Robert Pinkel's upper ocean physics group has extended its ability to monitor the oceanic water velocity field by construction of a new Doppler sonar. The sonar, which transmits between 65 and 90 kHz at a peak power of 32 kw, was first tested from FLIP in October 1978 off the California coast. Accurate velocity measurements were obtained to ranges in excess of 1.6 km and to depths of 1.2 km. Additional sonars are being constructed to enable multidirectional probing of the ocean interior, which is planned for a data collection cruise.

Physiological Research Laboratory

Scientists in the Physiological Research Laboratory (PRL) study the biochemical and physiological responses of organisms to the heterogeneous physical and chemical conditions of terrestrial and aquatic environments.

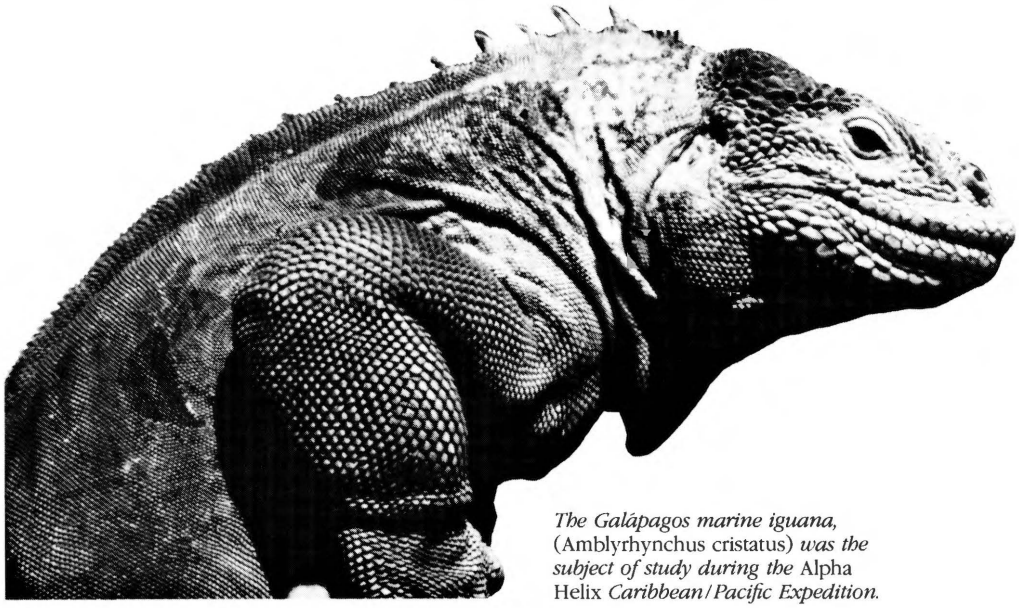
Dr. Jeffrey B. Graham continued his studies of the respiratory adaptations of air-breathing fishes. Following field studies in Panama, he returned with specimens of the burrowing swamp eel, *Synbranchus*, which are living in experimental habitats. Dr. Graham is currently studying the effects of burrow confinement, without water, on such factors as the respiration, nitrogen balance, and water retention.

Dr. Edvard A. Hemmingsen carried out studies on spontaneous gas bubble nucleation in aqueous systems *in vitro* and in single-celled organisms. It was discovered that cytoplasm is extremely resistant to cavitation; intracellular bubble nucleation requires gas supersaturations higher than those that produce profuse bubble nucleation in water or solutions.

Work on the cultivation of deep-sea animals and bacteria in the laboratory was continued by Dr. A. Aristides Yayanos. Samples were collected from the central North Pacific Ocean (5,700 m) and from the Mariana Trench (10,500 m). Besides showing that the amphipods are inactivated by decompressions, Dr. Yayanos has determined the oxygen consumption of deep-sea amphipods and extended the duration of captivity, at 580 bars pressure, to 17 days. His research has resulted in the establishment of several laboratory strains of deep-sea bacteria. During his observations of their physiology he noted rates of growth more rapid than previously thought to exist.

Dr. Harold T. Hammel, in collaboration with colleagues from Max Planck Institute for Physiological and Clinical Research, West Germany, investigated body fluid properties that determine the rate of salt and water elimination by the avian nasal salt gland and kidney. They obtained evidence for osmoreceptors in the head that exert control over kidney water excretion, but do not stimulate nasal salt gland secretion. However, these receptors appear capable of inhibiting the salt gland in response to hypo-osmotic stimuli. The presence of dual, but interrelated, control systems for sodium secretion (salt gland) and renal water excretion confers on marine birds an exquisite control of salt and water balance.

Drs. Fred N. White and Ralph A. Ackerman conducted field studies on the Galápagos marine iguana in which they evaluated



D. POPP

The Galápagos marine iguana, (Amblyrhynchus cristatus) *was the subject of study during the* Alpha Helix *Caribbean/Pacific Expedition.*

gas composition of the lungs during diving and acid base regulation as a function of body temperature. They showed that the lung oxygen supply accounts for aerobic dives of the durations observed at sea, a finding contrary to previous reports that anaerobic glycolysis supported diving activities. Their studies substantiated the contention that change in thermal state must be associated with appropriate and precise acid-base regulation in support of cellular function.

Studies by Dr. Luis Palacios, University of Barcelona, Spain, and Drs. White and Ackerman have delineated the conditions of lung gas composition at various temperatures in diving turtles. Temperature dependent critical lung oxygen tensions, below which anaerobic metabolism and lactic acid production increases, were identified. Undisturbed animals terminated diving at or above these oxygen tensions. At oxygen levels above the critical tension little carbon dioxide enters the lungs, a condition favoring hemoglobin-oxygen binding and extraction of oxygen at low partial pressure. The bulk of metabolically produced carbon dioxide is buffered in body fluids and released as a pulse when breathing is initiated. The capacity of such diving animals to compartmentalize carbon dioxide is an important component of diving, which extends aerobic diving time and access to lung oxygen stores.

The collaboration of Dr. Roger Spragg, UC San Diego School of Medicine, and Drs. Ackerman and White has resulted in quantitation of ventilation distribution in lower vertebrate lungs. The general assumption that monoexponential equilibration of test gases in the lung implies homogeneous distribution of ventilation has been used to evaluate both human and lower vertebrate ventilation patterns. The group found that this assumption, based largely on the parallel distribution of units of the human lung, is not valid for the turtle where the lung units are in series. A computer model of the lung is being developed, which will aid in predicting ventilation distributions over a range of respiratory states.

Dr. Ackerman also has investigated gas exchange, energetics, and temperature control of avian eggs. He studied, in cooperation with the San Diego Zoological Society, the problems of captive rearing of rare species such as Darwin's rhea and emu. His work at Salton Sea, California, revealed that the eggs of the pied-billed grebe, which are wet and housed in a floating nest, still manage to lose about 15% of their initial mass as water, a general requirement for avian eggs. This may be because of the number of pores per unit area of eggshell, which is 3-4 times that of other species. Grebes tend not to incubate during the day. Instead, eggs are prevented from overheating during the day by evaporative cooling and warmed during cool hours by the incubating parent.

Dr. Gerald L. Kooyman and associates and others have obtained evidence from the physical features of ventilation in whales and sea lions that helps explain the striking differences in respiratory anatomy between marine and terrestrial mammals.

Dr. Daniel P. Costa is near completion of a project on the energy requirements of sea otters. Determination of the diving activities of marine mammals and how these activities relate to physiology and ecology continues as a major part of field work in the antarctic, arctic, and elsewhere.

Visibility Laboratory

Scientists at the Visibility Laboratory have research interests in propagation of light in the ocean and atmosphere, interactions of light with the ocean, and computer processing of image information.

During the past year, the interest and activity in optical remote sensing of ocean properties have grown even greater. The focus has been on the effort associated with the Coastal Zone Color Scanner carried on NIMBUS 7, which was successfully launched in October 1978. This sensor provides synoptic images of the ocean surface that show subtle changes in ocean color related to macroscale physical and biological processes. Roswell W. Austin, as a member of the NASA (National Aeronautics and Space Administration) Experiment Team for this sensor, together with Dr. Raymond C. Smith, Dr. Wayne H. Wilson, and staff have continued to develop new measurement techniques. They also acquire and analyze surface truth data that can be used to develop and validate algorithms for extracting oceanographic information from the satellite data.

Laboratory staff organized and participated in two major cruises specifically to acquire surface validation data in conjunction with satellite overpasses. The first cruise was in November aboard R/V *Gyre*, operated by Texas A&M University, College Station, and covered the northern Gulf of Mexico. Where possible, the stations were arranged to place the ship within the swath of the sensor at the time of satellite overpass. This was done to gather measurements of the pertinent optical, biological, and physical conditions existing in the water at a point in the area covered by the sensor. These stations were selected so that scientists could record a range of water conditions to aid in "calibrating" the sensor. Optical conditions of the atmosphere were also documented to permit the atmospheric transmittance and path radiance effects to be removed from the satellite data. In February, similar measurements were made on the second cruise from R/V *New Horizon* off the California coast from Point Conception to the Mexican border.

A new project was initiated during the year to develop a data base of optical properties of ocean waters. The computer-stored information is to be filed by location and season and will contain data from a variety of sources that include in situ measurements at oceanographic stations and synoptic data over large areas obtained by optical remote sensing techniques. A new high-speed image-processing hardware unit with a high resolution color display terminal has been added to the laboratory's image-processing facility. This unit will greatly facilitate the analysis of multispectral images from remote imaging sensors such as the Coastal Zone Color Scanner, and it will also aid in the development and evaluation of algorithms for extracting ocean water properties from the multispectral data.

Two research activities in atmospheric optics sponsored by the Air Force were conducted by Richard W. Johnson's group. These activities are integral parts of an overall program to develop a thorough understanding of atmospheric effects upon the propagation of visible and infrared radiation through the atmosphere. Researchers will use existing optical data together with standard meteorological data to derive statistics and correlations, which will lead to the development of models suitable for operational forecasting of the optical conditions of the atmosphere from meteorological data.

The two activities are characterized by two basic data sets. The first activity is a continuation of the processing and analysis of data collected during several years of airborne measurements of atmospheric optical properties. These data consist primarily of volume scattering coefficient measurements made as a function of altitude, taken simultaneously with related optical and meteorological parameters. The research is currently directed toward identifying useful relationships between these profile data and the atmospheric aerosol distributions.

The second project involves the analysis of a similar, but ground-based data set that documents optical and meteorological parameters measured over a two-year period. These data have been collected in five northern European areas by scientific teams working on a NATO-sponsored research program. The analysis of these data by researchers at the Visibility Laboratory is being dovetailed with the analysis of the airborne data in an integrated attack on the general problem of developing models for the temporal and spectral variations in the optical state of the atmosphere.

Deep Sea Drilling Project

The tenth anniversary of continuous activity was marked by the Deep Sea Drilling Project (DSDP) this year as announcement was made of a significant new technological achievement, the development of a hydraulic piston coring system. The D/V *Glomar Challenger* traveled over 15,000 nautical miles during five legs in the Pacific Ocean. Shipboard scientific parties included 39 foreign researchers from 12 nations.

The goal of the sixty-second expedition was the study of changes in the ecology of the northern Pacific Ocean during the past 120 million years. The evidence is recorded in sediments that have accumulated in the mid-Pacific mountains and the Hess Rise.

Core samples revealed that sediments from most of the past 110 million years are missing and, therefore, much of the paleo-oceanographic record is absent. The missing sediments were probably removed from these two elevated regions during periods of subsea erosion. In addition, layers of hard chert frequently hampered the recovery of soft sediments interlayered with the chert. However, the sediments record the histories of rapid sinking of the mid-Pacific mountains and Hess Rise. From volcanic islands and platforms, perhaps similar to the present-day Galápagos Islands, they became submerged seamounts and plateaus of intermediate water depths within the first 10-20 million years of their existence.

Discoveries made during Leg 63 added to the history of the Pacific sea floor off California and Baja California. Cores were taken from seven sites; three off the coast of southern California, three off the west coast of Baja California, and one near the mouth of the Gulf of California. Twenty million years ago, a deep-sea trench lay off the coast of both Californias. Volcanic rocks recovered in dredge hauls from this area had been thought earlier to be related to the trench. Results of *Glomar Challenger* drilling showed that these volcanic rocks are probably *not* related to the trench, but are more likely related to a mid-oceanic spreading center, the East Pacific Rise, which intersected the continental margin off California about 17 million years ago. Fossil microorganisms found in cores provided evidence of changes in ocean currents that have an effect on climate. One site off Baja California provided evidence of a cooler climate interval about 9 or 10 million years ago. Studies of recovered fossil microplankton will aid in the reconstruction of major ocean current systems from the Pacific over the last 20 million years.

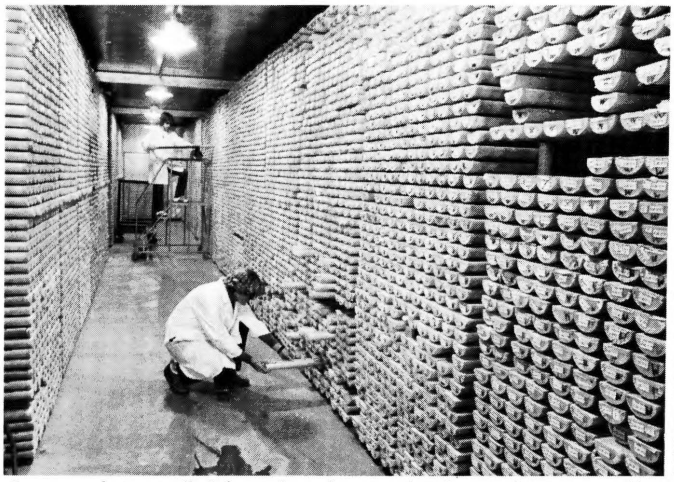
DEEP SEA DRILLING PROJECT

Student assistants Elizabeth Fogle, right, and Larry Rairden sample and record core data.

During Leg 64 rock and sediment cores were brought up from the deep-sea floor at the mouth of the gulf off Cabo San Lucas and from the northernmost large deep basin off Guaymas, Mexico. These cores prove the Gulf of California to be geologically very young and rapidly expanding. This expedition was made to test both the theory of sea-floor spreading and modern concepts of global tectonics in the gulf. The way new sea floor is created in a very young, narrow ocean bounded by nearby continental mountain ranges, which provide a large sediment supply to the sea, was also studied. In five holes drilled southeast of Cabo San Lucas, a transect crossing from ocean crust to continental crust was completed. Data from the transect revealed that in early stages of continental separation the continent edge is thinned and great subsidence occurs. At a hole, 2,000 m deep, granite was recovered that had once been exposed on land to weathering in an arid climate similar to Baja California. Only 11 km to the southeast, in water over 3,000 m deep, the earliest basalt lava crust involved in forming the new sea floor was sampled and found to be only 3.5 to 4 million years old. This is in agreement with the age predicted by results of earlier geophysical studies and proves that the new ocean is expanding at the rate of almost 61 m per 1,000 years.

A highlight of the work in the Guaymas Basin was the use of a new tool developed by DSDP engineers, the hydraulic piston corer, which is used on the end of the drill pipe. Employed for the first time, it was used to sample sediments from the continental slope off Guaymas; with the corer scientists recovered an unprecedented 153-m-long section of completely undisturbed, delicately layered sediments containing microscopic plant and animal remains. Preliminary shipboard studies of these cores suggest that they may contain details of annual climatic events dating back 300,000 years into the history of the formation of a new ocean.

Study of the area was continued on Leg 65. The mouth of the Gulf of California was chosen because it represents the northern extension of the East Pacific Rise; thus thought to be underlain by extremely thin, young crust forming as a result of sea-floor



DEEP SEA DRILLING PROJECT

Cores are being pulled from the refrigerated collection by E. Fogle (foreground) and L. Rairden. The average sample size is approximately ten cubic centimeters. Cores in this picture represent about one-fourth of the total West Coast Repository collection.

spreading. Because of the proximity of continental sources of sediments, the crust in this area, unlike that along most of the mid-ocean ridge system, is rapidly covered by enough sediments to "spud in" and drill, even in very young crust. Since, in addition, well-defined magnetic stripes are present in the area, the mouth of the gulf presents an optimum place to study the mechanism and timing of crustal growth. During two months of activity, seven holes were drilled into crystalline rock beneath the sediments. The combined results give a vivid picture of crustal formation. The crust here is seen to grow rapidly by repeated extrusions of pillow basalt along an axial zone of volcanoes or fissures, similar to those seen today in central Iceland. Although most of the sites were drilled within the sight of land, the basalts displayed chemical compositions of mid-ocean basalts with no evidence of continental contamination. Some of the youngest basalts had compositions that suggested rapid transport to the surface from sources in the earth's mantle without chemical change by partial crystallization and separation.

Scientists' study of the fossils in the oldest sediments at each site, and of the magnetic polarity of the underlying basalts showed the Gulf of California is presently opening at a rate of 5.6 cm per year. As a result, Baja California and southern California slowly move to the northwest along the San Andreas Fault. The magnetic anomalies observed at the mouth of the gulf can be explained by a source layer only 500 m thick, as originally postulated.

In addition to drilling, a series of geophysical experiments was conducted during Leg 65. These included the implementation and recovery of a self-contained, automatic seismic station in the sea floor about 3 km below the ocean surface, and the monitoring of seismic activity in the sea floor by means of a second seismometer lowered into another hole a few kilometers away. Also completed was a detailed logging program in several holes to determine the temperature, density, and porosity of the rocks in situ. One of the most intriguing results of these measurements was the discovery that the uppermost levels of the acoustic basement in one hole, near the ridge axis, are nearly at boiling temperature, suggesting that the ship had drilled near a magma chamber.

A successful test of a theory of evolution of deep-sea trenches, the recovery of an ice-like substance called clathrate, a gas-hydrate from sediments below the sea floor and data revealing the history of the continental margin off southern Mexico, 112 km southeast of Acapulco, were the major results of Leg 66. Shipboard scientists were able to examine the way in which the Cocos Plate converges with the North American Plate of southern Mexico and Central America. Earthquakes along the plate boundary indicate that the oceanic Cocos Plate is being thrust beneath southern Mexico and Central America. Leg 66 data show that slightly more than one half the sediments deposited on the sea floor and in the trench are accreted into the continental margin with the remainder being subducted to great depths. Investigators also discovered that, beneath a relatively thin sediment apron covering the modern slope, the oldest rocks were at the top of the slope and the youngest at the bottom, an inversion resulting from the accretion processes. The same scientific party was also able to reconstruct the history of the Mexican continental margin in this area documenting a 20 million year old transgression. The margin continued to subside until roughly 15-16 million years ago. Since that time the margin has risen from depths of 5 km to its present level, probably as a result of accretion of sediments beneath the overriding North American Plate.

The DSDP scientists investigated a transect offshore of Guatemala, an active continental margin where accretion and imbrication are thought to be the dominant tectonic processes. The transect is a companion to that drilled offshore of Mexico during Leg 66; but in contrast, samples analyzed during Leg 67 suggest that an accreted wedge of imbricated, oceanic rock and sediment was not encountered.

An oceanic reference site and eight holes drilled in the trench axis indicate that the Cocos Plate and its sedimentary overburden are disturbed only by normal faults along the seaward wall of the trench and as far landward as the toe of the continental margin. Compressive structures, such as reverse faults and folds, are rare or absent.

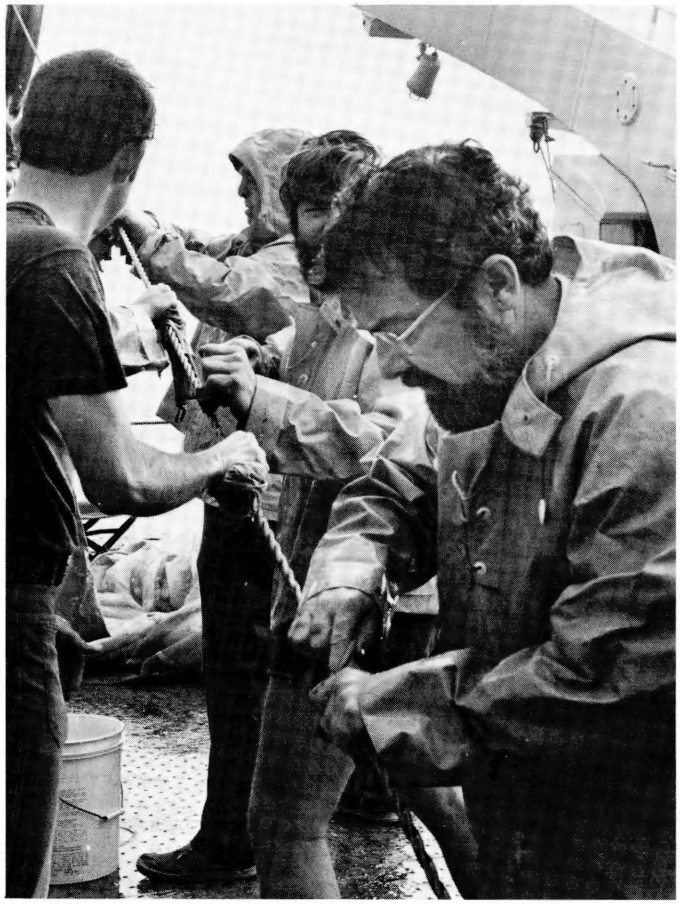
If the Guatemala transect is viewed as a test of the imbricate, accretionary wedge model, the results of drilling on the continental margin are surprising. Leg 67 sites recovered no uplifted or accreted oceanic rock and sediment; to the contrary, the uppermost 100 m of sediment contains benthic foraminifera reworked downslope from shallow depths. Secondly, the discovery of rock as old as the Upper Cretaceous within 3 km of the trench, beneath which oceanic crust of early Miocene is subducting, leaves little space for rock and sediment accreted during the intervening 50 million years of plate convergence. Thirdly, the regular stratigraphic sequence drilled, young on top to old beneath, indicates that the section is not cut by thrust faults, because imbricate faulting would reverse the order of rock age.

Both Leg 67 and Leg 66 recovered clathrate in cores from their continental margin sites. Melting of the ice from Leg 67 samples liberated greater quantities of gas than are soluble in water at in situ pressure and temperature. The regular association of vitric sand and clathrate in Leg 67 cores suggests that porosity greater than that of hemipelagic mudstone is a prerequisite for the accumulation of sufficient gas to form enough clathrate so that ice can be recovered at the rig-floor.

Marine Life Research Group

The Marine Life Research Group (MLRG) has a special interest in the Pacific and particularly in the California Current, which influences the California coast and the marine-related industries. Results from researchers in physical, chemical, and biological oceanography characterize this current and, when compared with data from other Pacific areas, resolve its special feature.

Dr. John A. McGowan and Patricia Walker have completed a study of the species and spatial structure of an important fraction of the zooplankton community (copepoda) of the North Pacific Central Gyre. They find a highly structured and very stable system with little seasonal change. This implies a high degree of population regulation. The regulation does not seem to involve physical heterogeneity, thus indicating that biological interactions may be the main regulatory forces. Additional studies of other fractions of the gyre's zooplankton (chaetognatha, amphipoda, and larval fishes, by Dr. McGowan's students) show similar and complementary results. A comparison of these results to results from the California Current shows that communities from the latter are much more heterogeneous and highly variable, indicating a relative lack of the regulatory forces at work in the gyre and perhaps a fundamental qualitative difference in the nature of such forces.



DR. E. L. VENRICK

Dr. John A. McGowan and technicians prepare sampling gear for launch from R/V Thomas Washington.

Drs. McGowan and Thomas L. Hayward had shown earlier that nutrient input to the euphotic zone of the gyre comes from upward mixing driven by subsurface processes rather than by surface-driven convection during the seasonal change of the mixed-layer depth. The mixing process seems to be associated with shear instabilities accompanying an up-and-down movement of water (perhaps internal waves) that is most intense in the steepest part of the nutricline. Further studies have shown the regular presence of this process and that it seems to be associated with a large-scale nutrient intrusion from the north or northeast. This intrusion is also present in the California Current.

During the year Dr. Elizabeth L. Venrick completed a study of the physical, chemical, and biological characteristics, lateral extent, and heterogeneity of the central North Pacific environment at latitude 35°N and its relationship to a long-term study site at 28°N, 155°W. The primary data were collected in the spring of 1976 along a transect from California to Japan. In July 1977 a segment of this transect was repeated. Principal-component analysis was used to reduce the physical-chemical data into four axes by means of which five environments were identified along the 1976 transect: the California Current, the Eastern North Central Pacific (ENCP), the Western North Central Pacific (WNCP), cold core stations (presumably meanders or eddies from the Kuroshio Extension), and the Kuroshio Current. The biological characteristics of these environments were assessed by means of a chlorophyll index, derived from a second principal-component analysis. The ENCP was similar environmentally and biologically to the study site and was significantly more oligotrophic, nutrient deficient, than the other environments. The chlorophyll index within the ENCP showed a marked temporal and spatial stability, greater than that in the WNCP, which may reflect the reduced variability observed at mid-latitudes by physical oceanographers in the eastern portion of northern oceans.

Analysis of the vertical distributions of phytoplankton species at 28°N, 155°W is continuing. The study is based upon identification and enumeration of species in samples collected from the surface to 175 m, spaced as closely as 5 m through the chlorophyll maximum layer, 100-140 m. Preliminary analysis suggests that individual species are not distributed independently along the axis of environmental gradients, in this case, the vertical axis, as has been shown to be true for terrestrial vegetation. Instead, a sharp transition zone near 90 m divides the phytoplankton into an upper "nutrient-limited" association and a lower "light-limited" association.

A study of the long term, 20-year monthly variability of macrozooplankton abundance in the California Current by graduate student Patricio A. Bernal has shown several large anomalies. These seem to be related to variations in the intensity of large-scale oceanographic and/or meteorological processes that influence the advection of low-salinity, high-nutrient subarctic water into the California Current.

Margaret D. Knight has compared the larva and developmental stages of a species of krill, *Euphausia eximia*, from samples taken across the species' range. The larvae showed a significant difference in morphology between forms from the California Current and from the South Equatorial Current and Peru-Chile Current. This variation may be evidence of genetic divergence and suggests that the oxygen-deficient warm waters of the eastern tropical Pacific may form an effective barrier between North Pacific and South Pacific reproductive populations of the species. Significant differences in morphology were found as well during a preliminary survey of adults and, in samples examined, the southern limit of the northern form of *E. eximia* was about 2°N.

Dr. Edward Brinton's study of distributions and life cycles of euphausiid crustaceans in the California Current has recently focused upon behavioral reactions to simulated predators, as seen in different rates of capture by different samplers. It was not surprising that nets with anterior towing bridles elicited stronger escape responses by the large, active zooplankton than nets towed forward by means of a line extending upward. However, it was surprising to find that both large and small species begin to avoid nets after reaching the same size, rather than the same stage of development. Also, males and females react differently at comparable stages, with females most strongly sensing the approach of nets at the onset of maturity, and males considerably later.

Tetsuo Matsui is estimating the population densities of the rattail fish, *Coryphaenoides acrolepis*, and the sablefish, *Anoplopoma fimbria*. In comparing videotape fish sightings from the Remote Underwater Manipulator (RUM) in the San Diego Trough with visual observations made from the submersible *Alvin* off Santa Catalina Island off the coast of California, he found a notable discrepancy in the respective counts. The black and white videotape used on RUM lacks sufficient contrast, and most fish (for example, *Sebastolobus*, a thornyhead of the family Scorpaenidae, which is present in substantial numbers in visual counts) were apparently not countable. Matsui will analyze colored stereo photographs also taken during the *Alvin* fish surveys to improve or complement the visual counts (for example, sablefish, which apparently avoided the submersible and were usually not seen from the side-viewing ports where counts were made, should appear in the photographs).

Dr. Lanna Cheng continues to work on the zoogeography and ecology of the oceanic sea-skaters, *Halobates*, the only genus of insects to colonize the open sea. With the help of John D. Ott, Dr. Cheng has begun to map the locations of all of the surface tows collected over the past years. There are already some 3,500 stations in the computer bank, over 20% of which contain specimens of *Halobates*. When all the available sample data have been entered, Dr. Cheng will be able to relate specific *Halobates* distributions in the open ocean to some of the physical and chemical features peculiar to the air-sea interface where the sea-skaters live. Dr. Cheng has found that oceanic *Halobates* possess a cuticle that virtually excludes the penetration of damaging ultraviolet light; this is presumably an essential adaptation for the sea-skater to live on

A. L. SHANKS/J. D. TRENT

Divers Alan L. Shanks (left) and Jonathan D. Trent (right) collect marine snow with a 50 ml syringe. Large particles are ~2 cm long.

the open ocean. She has also found high concentrations of cadmium in these oceanic insects and is investigating the uptake of this heavy metal by the sea-skater. Preliminary uptake experiments indicated that more of the cadmium in *Halobates* came from drinking seawater than was taken up from food.

Jonathan D. Trent and Alan L. Shanks are studying large particles called "marine snow," so named by bathysphere divers who first encountered the phenomenon. These particles, also called "macroscopic aggregates," are 0.05-20 cm long and are composed of small, loosely aggregated particles. The marine snow particles are very fragile, and their extreme friability makes them impossible to study by conventional shipboard techniques. The two researchers developed a variety of sampling techniques for studying the role of these particles in the marine environment. They have described the snow as microhabitats for small organisms and a mechanism for altering food chains, as microscale nutrient patches and areas of isolated and concentrated chemical activity, and as mediators in vertical transport of particles.

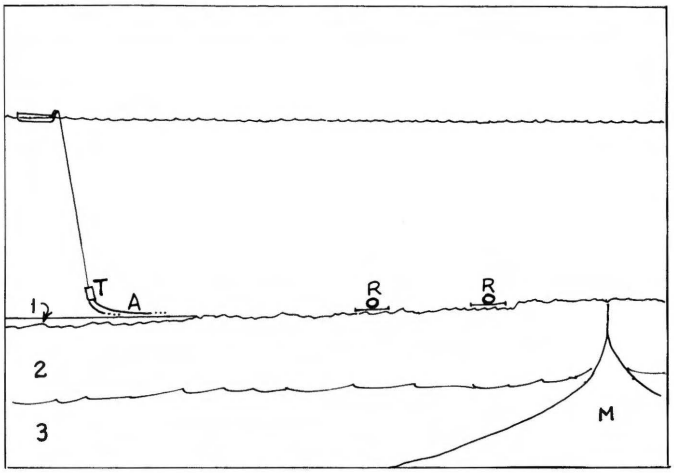
The distribution of marine snow in surface waters was investigated in transects across the northern and equatorial Atlantic and a transect 320 km off San Diego. Trent and Shanks also quantified the vertical distribution of marine snow in the water column, surface to 1,300 m, using research submersible *Alvin*, operated by Woods Hole Oceanographic Institution, Massachusetts. The properties of marine snow and the snow's remarkably wide distribution, in different water masses and at great depths, suggest that these particles may be an important detail in the sea's ecological structure.

Andrew Soutar and Dr. Stanley A. Kling have pursued application of the core-sediment trap dating methodology to the San Nicolas Basin off the California coast. Their results suggest that most of the metals associated with man's activities are deposited in the inner basins. However, they found that lead appears at present to be carried by air at substantially higher levels than was the case in preindustrial times. The lead sinks to the bottom of the basin and is subsequently diluted by the benthos.

Parallel studies in cooperation with Dr. Isaac R. Kaplan, UCLA, have determined the quantity and types of petroleum hydrocarbons that reached the southern California basin sediments in the preindustrial times. Furthermore, an order-of-magnitude increase of hydrocarbons that can be related to petroleum use has been documented for the inner basins of Santa Barbara and San Pedro, California. In addition, a decline of burrowing structures towards the surface sediment in the San Pedro Basin suggests a transition from aerobic to anaerobic bottom conditions some 20 years ago as a consequence of environmental change.

Other sediment studies by Soutar and Dr. Kling, for bioclimatological evaluation, include precision cores of varved sediments off Guaymas, Mexico, (taken in cooperation with Centro de Investigación Científica y de Educación Superior de Ensenada [CICESE] and the Mexican Navy) and a 150-m piston core (taken by Deep Sea Drilling Project scientists) from the same area. Subsampling of the cores, in cooperation with researchers from Texas A&M University, College Station, and UC Berkeley, should establish its geochronology. New studies already suggest that the deep piston core covers, in considerable detail, at least the past 100,000 years. Preliminary results of a study by Timothy R. Baumgartner, CICESE, and associates on the near-surface sediments indicate that diatom productivity in the Gulf of California is directly affected by broadly developed El Niño conditions in the eastern Pacific.

Dr. Charles S. Cox and co-workers for the first time tried out a new method of geophysical soundings during the international cooperative Rivera Submersible Experiment (RISE), off the southern tip of Baja California. The method consisted of injecting electromagnetic energy into the crustal rocks below the ocean. The signals were received by electrical detectors at distances up to 15 km. The measured intensity gives information on the electrical conductivity of lithospheric rocks.



DR. C. S. COX

Method of electromagnetic sounding during RISE is shown. The transmitter T was powered through a cable from R/V Melville. *The antenna A, 800 m long between electrodes, formed a horizontal electric dipole on the sea floor. Signals were detected by receivers R. Layers 1 and 2 refer to crustal layers. M is a magma chamber thought to underlie the East Pacific Rise.*

Joseph L. Reid and Arnold W. Mantyla are extending their early studies of the mid-depth circulation of the Pacific Ocean and are examining the deep and abyssal circulation and distribution of water characteristics. The transports recognized at present are of abyssal waters northward (cold, high in salinity and dissolved oxygen, low in nutrient content) and deep waters southward (low in oxygen, high in nutrients). Reid and Mantyla find, in addition, that the large-scale gyres known at the surface extend in a weakened and slightly altered form to depths below 3,000 m. The exchanges are not directly north-south, but the waters circulate around various deep and abyssal cyclonic and anticyclonic gyres as they progress. The waters mix both vertically and laterally during this circulation. The deep layer, 1,500-3,000 m, is formed from a mixture of the abyssal and overlying waters; it is intermediate in temperature and salinity, but because of the long residence time the deep layer is very low in dissolved oxygen content and correspondingly high in nutrient concentration. As a result, the highest nutrient concentrations of the deep ocean are found in the North Pacific. This layer, which lies deep in the North Pacific, extends southward and rises across the Antarctic Circumpolar Current. It provides the high nutrient concentrations of the near-surface Antarctic region.

As part of the data collection for this study, measurements were made in the Marianas Trench—the greatest depth yet recognized in the ocean. A free-fall collecting apparatus was used, and water samples were collected from a depth of 10,933 m. The abyssal water characteristics were not significantly different from those at the surrounding sill depths of about 6,000 m, indicating that below the sill depth there exists a deep, nearly homogeneous layer about 5 km thick.

Neurobiology Unit

The Neurobiology Unit, directed by Dr. Theodore H. Bullock, is part of the Marine Biomedical Program that enlists scientists from the University of California, San Diego School of Medicine and Scripps Institution of Oceanography in projects of joint interest to marine biology and medicine. These range from hearing in sharks and dolphins to electroreception in lampreys. The main common denominator of current activities is the processing of sensory information, particularly from receptors in lower vertebrates.

Dr. Bullock had an unusually active year of speculating and synthesizing—generating guesses and overviews for symposia about comparative audition, information processing, and spikeless neurons. Together with graduate student Vladimir S. Gurevich, he also generated a review of all Soviet work on the brain and psychobiology of cetaceans, covering some 360 references. Together with Drs. Robert Galambos and David L. Woods, he began collaboration with Dr. Sam H. Ridgway, Naval Ocean Systems Center, San Diego, on hearing in dolphins by recording averaged evoked potentials in the awake animal. This permits rapid assessment of the acoustic effectiveness of its brain of different kinds of sounds and combinations of sounds. Another project is the localization of the highest center in the forebrain of elasmobranchs, sharks and skates, that receives and processes input from the electrosensory receptors in the skin—the classical ampullae of Lorenzini. Dr. R. Glenn Northcutt, University of Michigan, Ann Arbor, also did this by averaging evoked responses and marking the hot spot of response for microscopic examination.

Dr. Northcutt is also involved in other projects on the pathways and destinations of electroreceptor, visual, olfactory, and auditory input in the brains of fishes. Together with Dr. David A. Bodznick, a number of species have been examined including elasmobranchs, hagfishes, lampreys, lungfish, and several unusual types of chondrosteans and holosteans. The methods used include "experimental anatomy," where amino acids, peroxidase or de-oxy-glucose is distributed by the active nerve cells and then visualized by cytochemical, enzymatic, or autoradiographic techniques. Similar methods are in use by Dr. William M. Saidel on the visual system of octopus.

In the laboratory of Dr. Walter F. Heiligenberg several predoctoral and postdoctoral associates employ behavioral and neurophysiological strategies to study the evaluation of electrosensory information by gymnotoid electric fish. They have focused on the JAR (Jamming Avoidance Response) in the species *Eigenmannia*. In response to the contamination of its own continuous, quasisinusoidal EODs (Electric Organ Discharges) by those of another fish, this animal shifts its EOD-pacemaker frequency away from that of its neighbor. This behavior is controlled by modulations in phase and amplitude of electroreceptive afferences that result from the mixing of the two EOD signals. Phase and amplitude modulations are encoded by two types of electroreceptive units. Pair interaction between populations of higher order representatives of such units from two different areas of the body surface yield an evaluation of these two variables, and these evaluations cumulatively contribute to the control of the pacemaker. The JAR is thus driven by a distributed algorithm that computes electroreceptive afferences in a somatotopically organized network of electroreceptive neurons.

Visiting scientist Dr. H. Scheich, Zoological Institute, Darmstadt, Germany, worked on vocalizations in a social group of emperor penguins through the cooperation of the Hubbs-Sea World Research Institute, San Diego. Through the same type of cooperation graduate student Jeffery T. Corwin and two visiting scientists worked on hearing in lemon sharks. Two other visiting researchers worked on posture and equilibrium in fish and on information transmission from receptor to second-order brain cell in the catfish lateral-line system.

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. J. Freeman Gilbert has two related major research projects underway. Both use data from the new IDA (International Deployment of Accelerometers) seismographic network and both rely upon network processing procedures. The first project is devoted to the accurate determination of frequencies and attenuation parameters of the earth's free oscillations. To give an idea of the accuracy attainable, the result of the earth's fundamental radial mode is quoted. Its frequency is 0.814664 mHz $\pm$ 4 ppm and its quality factor Q is 5700 $\pm$ 4%. The second project is devoted to the estimation of low order moments of earthquake forces. For a deep

event, Honshū, Japan, the first moments adequately represented the source. For a shallow event, Oaxaca, Mexico, higher moments are necessary.

Dr. Jonathan Berger continued the direction of Piñon Flat Geophysical Observatory, sited between the San Jacinto and San Andreas faults, where the seismotectonics of southern California are studied. Currently under development is the design and construction of a 500-m liquid tiltmeter and the study of horizontal benchmark stability with a recently completed laser optical anchor.

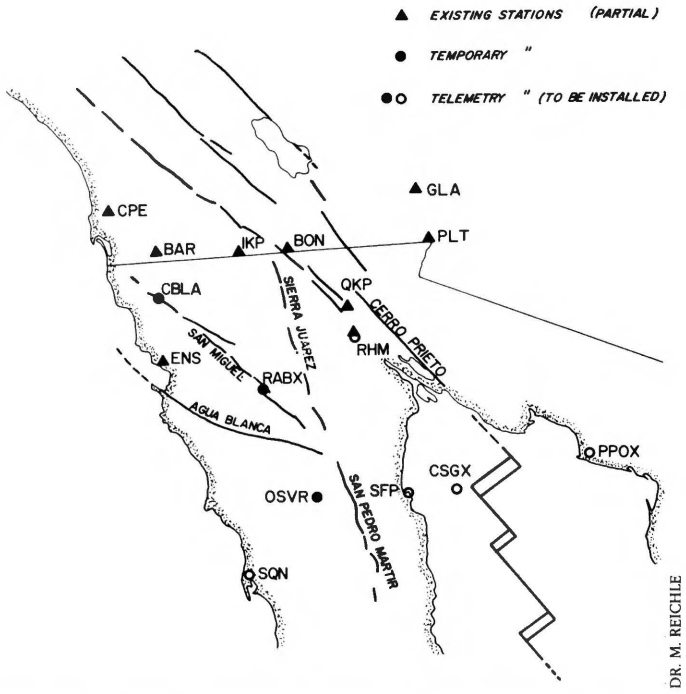
A global network of very long-period seismic stations, Project IDA, has been under development for several years, directed by Dr. Berger and Dr. Gilbert. This 15-station network was primarily designed for the study of the earth's free oscillations. Stations were recently installed at Eskdalemuir, Scotland, and at Guam, and installations are planned at the Seychelles Islands and at Falkland Island.

Dr. Robert L. Parker has continued to work on inverse problems. Working with Drs. Jan D. Garmany and John A. Orcutt, he was able to obtain a solution to the tau-p travel-time inverse problem of refraction seismology. Dr. Garmany had shown that when depth is considered as a dependent variable the pattern becomes linear, and this fact permits a linear-programing approach to be used, which yield best possible results for bounds on velocity-depth solutions.

Sir Edward C. Bullard continued his research on nuclear waste disposal and on the origin of the earth's magnetic field.

Dr. James N. Brune and his students continued their seismic hazard studies that included four major investigations. Numerical modeling of earthquake strong ground motion confirmed the effects of rupture focusing. The second was the recording and interpretation of anomalously high accelerations of up to 0.6g from a moderate earthquake (magnitude $\sim$ 5) recorded on IGPP's Mexicali Valley cooperative strong motion array. The third investigation was of the large Mexican earthquakes near Oaxaca and Petetlán. The fourth was the relocation of Baja California earthquakes of the last 40 years, which show that most of the activity south of San Diego has been concentrated along the San Miguel fault zone that strikes in the direction of Tijuana, Baja California, and may connect with the Rose Canyon fault zone in San Diego.

Dr. Michael S. Reichle is working with Dr. Brune on installing a telemetering network of seismic stations in northern Baja California. This is a cooperative project with the Centro de Investigación Científica y de Educación Superior de Ensenada to study the tectonics of northern Baja and to examine the seismic hazards of faults in that region. Dr. Reichle has also been involved in seismic studies following recent large earthquakes in central Mexico.



DR. M. REICHLE

Map shows position of seismic stations from San Diego down through northern Baja California.

In an extension of his previous work on San Diego earthquakes, Richard S. Simons relocated all earthquakes in the San Diego area from 1975 through 1978 and has identified and eliminated all man-made explosions.

Dr. Hugh Bradner maintained a sonobuoy array in readiness for monitoring aftershocks of nearshore earthquakes and worked on many aspects of the Deep Undersea Muon and Neutrino Detection experiment.

Using Bernstein's inequality, Dr. George E. Backus has devised an algorithm for computing infima of N-dimensional real polynomials on arbitrary sets. He has extended the Bernstein method to vector- and tensor-valued polynomials, which makes it directly applicable to the determination of the intrinsic stability of multidimensional systems, for example, multidimensional filters and prestressed anisotropic elastic media such as occur in earthquake source regions.

Dr. Richard A. Haubrich has been involved with high resolution spectrum analysis methods of the all-pole or maximum-entropy type that have now been extended to treat multiple channels. Computational comparisons between a bidirectional least squares and the standard Burg method are being carried out to investigate the correlation between long period polar motion data and possibly related phenomena such as sun spot numbers.

Drs. Walter H. Munk, Peter F. Worcester, Gordon O. Williams, and Robert A. Knox and Bernard D. Zetler and graduate students, continued the ocean acoustic tomography study in collaboration with scientists from three other institutions. Significant achievements during the year included successful resolving of stable multipaths over a range of about 1,000 km and satisfactory agreement between measured travel times of individual paths and those computed for the same paths from ray theory by use of a mean sound speed profile. Tidal studies included tidal variability in acoustic transmissions and the determination of tidal datum planes for boundary problems.

Dr. John W. Miles continued his work on nonlinear waves. He developed variational formulations for solitary waves in stratified shear flows and for solitary Rossby waves. He also studied the propagation of solitary waves in water of variable depth and showed that such propagation necessarily implies the excitation of secondary wave trains.

Dr. W. Kendall Melville and UC San Diego graduate student Peter Chang concluded an experimental and numerical study of the propagation of solitary waves in channels of slowly varying breadth. Dr. Melville also concluded an experimental study of the Mach reflection of solitary waves and continued work on problems of air-sea interaction with laboratory experiments on the kinematics and dynamics of breaking waves.

Dr. Myrl C. Hendershott and graduate student David C. Chapman studied internal wave trapping and resonant enhancement in theoretical geometries intended to model submarine canyons. Chapman, additionally, has made time lapse motion pictures of surface slicks over La Jolla Canyon for comparison with the above results.

Dr. Richard L. Salmon is using computer simulations of the equations of motion and a "closure theory" of turbulence to study the mechanisms of growth and decay of storms in the atmosphere. The two methods will eventually be applied to "oceanic storms" such as the mesoscale eddies observed in the MODE experiment.

Dr. Ralph H. Lovberg's program of diagnostic experiments being conducted at the UCLA Tokamak fusion facility has been completed. Results of the most recent measurements are that instability levels in the Microtor machine are less than $\Delta u/u = 0.01$ for the range of spatial and temporal wavelengths observed. He concludes that instabilities in this range are not a source of plasma loss. Work has been initiated on a new thermonuclear fusion concept called the gas-embedded pinch.

Dr. Robert H. Stewart continues to use dekameter radio waves to

measure ocean surface waves and currents and satellite data to study the world's oceans in order to determine if satellites can accurately measure the spectrum of ocean waves and oceanic rainfall.

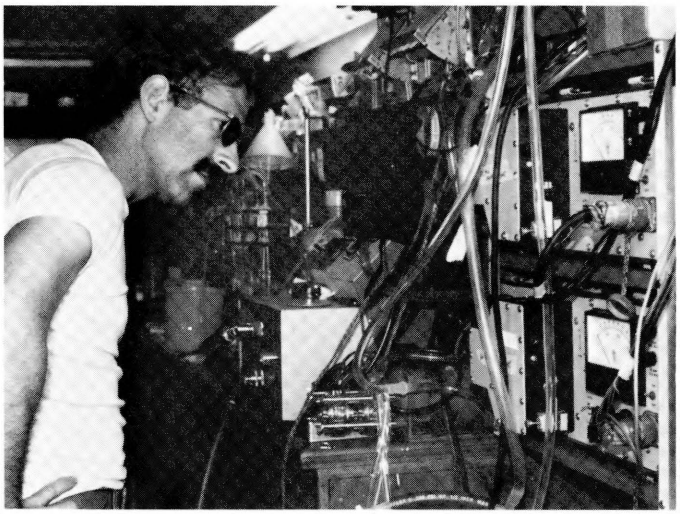
Three Cecil H. and Ida Green scholars worked at IGPP this year. Dr. Thomas G. Masters, Cambridge University, England, in collaboration with Dr. Gilbert studied the source mechanisms of deep and shallow earthquakes using data from the Project IDA instruments. The source mechanisms have been used in the retrieval of free oscillation multiplet frequencies. Dr. Christopher H. Chapman, University of Toronto, Canada, continued his theoretical research on seismic body-waves. He has extended his technique for computing WKBJ (Wentzel-Kramers-Brillouin-Jeffreys) seismograms to apply exactly in a spherical model and to include long period corrections. Dr. Chapman, in collaboration with Dr. John A. Orcutt, is using WKBJ seismograms to interpret seismic refraction studies. Dr. Paola Rizzoli, National Research Council, Venice, Italy, continued a study of the stability properties of solitary topographic Rossby waves and a study of the oceanographic properties and modeling of circulation in the northern Adriatic Sea with specific attention to the use of NIMBUS-7 remotely sensed data.

Institute of Marine Resources

The Institute of Marine Resources (IMR) pursues research, education, and public service in the area of marine resources and their utilization. Scientists at IMR seek to improve the nation's supply of organic and mineral materials, to harness the energies of the sea, and to advance knowledge about ocean circulation, wave climate and sediment transport near the coast, marine pollution, and waste disposal at sea. The institute has facilities on the Davis and San Diego campuses and is directed from Scripps by John D. Isaacs.

A brief account of the principal IMR activities at Scripps follows. A complete description of all activities is published in annual or biennial reports of IMR, Food Chain Research Group, and UC Sea Grant College Program.

The Food Chain Research Group (FCRG) reported several studies related to plankton in ocean food webs. A series of manuscripts and reports marks the completion of a detailed study of the taxonomic composition and standing stocks of microplankton from the central North Pacific. These data are useful to those concerned about the increasing levels of atmospheric CO_2, from fossil fuel combustion, and of interest to those who wish to assess the oceans as a sink for this CO_2. The extent of calcium carbonate deposition as coccoliths is of direct interest, and it can be quantitatively assessed from these data along with previously published values for plankton photosynthesis. The results suggest that the rate of coccolith carbonate formation is 10% of total photosynthesis, or about 5 grams carbon m^{-2} $year^{-1}$.



INSTITUTE OF MARINE RESOURCES

Measurements of chlorophyll fluorescence, an indication of the phytoplankton abundance off southern California, are taken by Edward H. Renger aboard the Ellen B. Scripps. *Two fluorometer gauges are visible at right.*

The group has studied the dynamics of plankton production in the Southern California Bight since 1974. They have compared the time series of plankton production with physical and chemical changes in the bight. This comparison revealed that about one-half of the variability in production was related to the depth of nutrient concentration gradients.

In the bight region, nutrients are usually depleted at the surface, and their concentrations begin to increase at depths of 10 to 50 m. The physical processes, such as seasonal and episodic upwelling, that move these gradients up and down appear to be the driving forces for plankton production. The gradients are deep and production low in climatically warm years and shallow with production high in cold years.

Collaboration with colleagues at the La Jolla, California, laboratory of the National Marine Fisheries Service has been helpful in understanding the temporal pattern of anchovy recruitment in relation to plankton production. Curiously, anchovy recruitment is best not when plankton production is highest; but rather when production is lower, the surface waters are well-stratified, and particular species of plankton are found aggregated in a layer just below the thermocline and in the top of the nutrient concentration gradients.

Members of FCRG have contributed expertise to two large National Science Foundation programs. The first is the Controlled Ecosystem Pollution Experiment (CEPEX) program at Vancouver Island, British Columbia, which involves the study of plankton—fish food webs enclosed in giant plastic bags. The second is the antarctic Ross Ice Shelf Program (RISP) to assess plankton and benthic food webs beneath the Ross Ice Shelf.

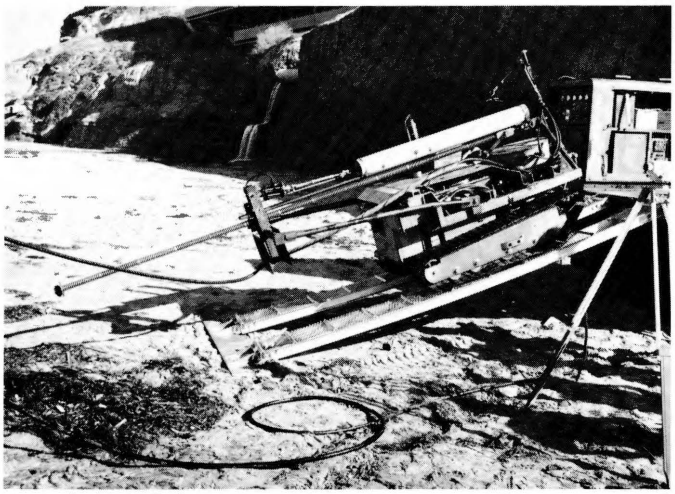
Other plankton work in IMR includes studies of Dr. William H. Thomas on the time series of phytoplankton species changes off Scripps. He is also investigating the effects of organic compounds in petroleum refinery effluents on natural phytoplankton populations.

Dr. Richard J. Seymour's Nearshore Research Group (NRG) engages in studies of beach morphology, coastal wave climate, and dynamic breakwater performance.

Changes in beach profiles and offshore bathymetry were studied at Torrey Pines Beach, Del Mar, California, in November 1978 as part of a major field experiment undertaken by the Nearshore Sediment Transport Study. Significant beach-face erosion was recorded during a localized storm while very extensive measurements of waves and currents across the surf zone were also under way. Dr. Seymour and graduate student David B. King, Jr., are investigating the correlations between the beach erosion and the causative hydrodynamic forces.

The investigations of wave-induced beach morphological changes have indicated the need for securing rapid bottom-profile transects through the surf zone in conditions of very high waves. To provide this capability, the group developed an instrumented, remotely controlled tractor to use as a profiler. The profiler measuring instrumentation set, which consists of a precision-gyro stabilized pitch-and-roll sensor, track odometers, a flux-gate compass, and the data-logging equipment was developed by Alan L. Higgins. The tractor delivery system, including controls and all mechanical systems, was designed and built by David P. Bothman, a UC San Diego engineering student. The profiler provides very accurate profiles to distances of 400 m from shore and operates in breaking surf exceeding 2 m in height.

A study of damaging seiche within Mission Bay, San Diego, California, was begun for the U.S. Army Corps of Engineers. Long-period waves were measured both inside Quivira Basin and at the end of Ocean Beach Pier. In addition to the long-period wave measurements at several locations, directional measurements of wind waves are being made outside the Mission Bay entrance. Correlations of the seiche in the internal basins with the external climate of both long- and short-period waves are being undertaken



Remotely controlled tractor.

by Dr. Seymour. The group conducted a similar study of long-period waves for National Aeronautics and Space Administration near Point Arguello, north of Santa Barbara, where it is proposed that barges unload space-shuttle hardware and booster rockets.

Higgins and Dr. Seymour performed a study for the California Coastal Commission on southern swell in which they used four wave-measuring stations between Imperial Beach and Oceanside as a noncoherent intensity array to estimate deep-water wave direction. The wave measurement system used in these studies, which includes 17 sites and 42 instruments automatically polled every ten hours, was developed by Meredith H. Sessions.

An experimental mobile Tethered Float Breakwater, developed by David Castel based upon a concept conceived by Isaacs and investigated by Dr. Seymour, was installed by the U.S. Navy and the Army Engineers north of Imperial Beach at a depth of 6 m. Performance data are being analyzed by Castel and wave measurements are obtained through the NRG wave data gathering system.

The California Sea Grant College Program is headquartered on the Scripps campus. Through funds provided from federal, state, and private sources, the program advances marine resource development and conservation in California through applied marine research, and educational and advisory services to the public and to special user groups throughout the state.

An integrated research program is achieved through 60 research projects in coastal resources, aquaculture, fisheries, new marine products, and energy resources research and development. Projects being conducted at Scripps are described below.

Ocean education for the public is fostered through a project under the direction of Donald W. Wilkie at the Vaughan Aquarium-Museum. Docents conduct field trips at the aquarium and a special outreach program that teach marine resources to local school children. Educational workshops for teachers and public exhibits contribute to this effort.

Francisco V. Vidal, Isaacs, and Dr. Kenneth H. Nealson have been investigating a thermophilic marine bacterium that fouls the cooling water pipes of power plants. They are developing a control method that will reduce heat exchange losses and improve plant efficiency.

The two projects conducted by Dr. Mia J. Tegner relate to fishery resources in kelp beds. The first project is directed toward gaining an understanding of the natural history and ecology of the major abalone species of southern California in order to determine the scientific and economic feasibility of various methods of enhancing abalone stocks. The survival success was monitored of trial abalone plantings made at Santa Rosa Island and Point Loma, California. In the second project Dr. Tegner is developing a multispecies management plan for kelp-bed resources by assessing population size of sea urchins and their interactions with other species.

Investigations on the development of new chemical products from marine organisms are being conducted by Drs. William H. Fenical and D. John Faulkner. Dr. Fenical is studying extracts from marine plants that have interesting pharmacological and biocidal properties. The development of new agricultural products from extracts that show insecticidal possibilities is being researched by Dr. Fenical as is the elucidation of the structure and activity of compounds from a brown seaweed that indicate antileukemic potential. Dr. Faulkner's research has concentrated on extracts from marine organisms, in particular sponges, that show pharmacological activity potentially useful in the development of new drugs.

Drs. Michael M. Mullin and Reuben Lasker and graduate student F. Kim Devonald studied the feeding habits of the jack mackerel larvae in an attempt to understand what planktonic densities are required for survival and how population sizes might be estimated. Results will serve as a basis for estimation of larval survival in any given spawning season.

Gerald G. Kuhn and Dr. Francis P. Shepard continued studies on sea cliff erosion in northern San Diego County. They have compiled geological data and historical and photographic documentation of bluff erosion for use by the San Diego Coast Regional Commission and local developers and planners.

Dr. Douglas L. Inman has completed a study of a crater-sink bypass system at Agua Hedionda Lagoon. The object of this study was to design and test a low-cost technique for sand management in lagoons and harbors.

Dr. Clinton D. Winant and graduate student Alan W. Bratkovich are conducting a field study of coastal circulation and temperature fluctuations of the San Onofre, California, nuclear power plant. These measurements will be used for background information on the current and thermal regime and for satellite overflight data comparisons and three-dimensional modeling of the dynamics of the cooling water outfall.

The Nearshore Sediment Transport Program, a multiinstitutional coordinated study, conducted a major joint field experiment in 1978 at Torrey Pines Beach, which involved three Scripps researchers. Dr. Seymour investigated onshore and offshore transport of sediment, Dr. Inman studied the longshore sediment transport, and Dr. Robert T. Guza investigated current and surface elevation within the surf zone.

M. KIRK

Scientist releases content of suspended sediment sampler.

SEAGOING OPERATIONS

At the beginning of fiscal 1979, research vessels *Melville, Thomas Washington, Alpha Helix,* and *Ellen B. Scripps,* and research platforms FLIP and ORB were in operation. Our then-uncompleted research vessel *New Horizon* was still at the Atlantic Marine shipyard, Jacksonville, Florida. The five vessels and two platforms spent a total of 1,041 days at sea and covered 111,898 nautical miles in the Pacific and Atlantic oceans, the Red Sea, and the Mediterranean Sea.

As the year began, *Melville* was in the Red Sea for deep-tow/geochemical studies in that rifted zone; her program included a brief stop at Jiddah, Saudi Arabia. In mid-July *Melville* left Port Said, Egypt, for Cádiz, Spain, on a deep-tow survey of the eastern Mediterranean Sea, with Dr. Fred N. Spiess as chief scientist. Dr. Peter F. Lonsdale took over at Cádiz for a 34-day leg to St. George, Bermuda, with two deep-tow surveys in the eastern Atlantic near the Canary Islands and two in the western Atlantic near Bermuda, as well as investigation of the interaction between sedimentary geology and physical properties of the benthic boundary layer en route. In mid-September, with David L. Ripley in charge, *Melville* left Bermuda for San Juan, Puerto Rico, taking plankton net tows along the way. At San Juan, Dr. Wolfgang H. Berger came aboard with his team of sedimentary-box-coring experts who took samples in the tropical and temperate Atlantic on either side of the Mid-Atlantic Ridge and off West Africa. Joseph L. Reid and physical oceanographic associates met *Melville* in Montevideo, Uruguay, in early November and then departed for the stormy South Atlantic to deploy current meters and take hydrographic casts in and to the east of the Argentine Basin. The next scheduled port was Punta Arenas, Chile, near Cape Horn, but because of the political tension between Argentina and Chile, *Melville* was diverted back to Montevideo.

Once political conditions stabilized, shortly after Christmas, *Melville* left Montevideo on a direct run to Punta Arenas. There Dr. Worth D. Nowlin, Jr., Texas A & M University, College Station, became scientist-in-charge for *Melville*'s third International Southern Ocean Studies operation in five austral summers. Dr. Nowlin and associates recovered, repaired, reloaded, and redeployed current meters and tide gauges set out the previous year in Drake Passage. Dr. Steven Neshyba, Oregon State University, Corvallis, conducted eight hydrographic stations and sampled chlorophyll in seawater and the dissolved gases in the surface waters and atmosphere north along the meridian 90°W; *Melville* arrived in Balboa, Canal Zone, early in March. Under the direction of Frederick A. Van Woy, *Melville* made a direct transit to Manzanillo, Mexico, as scientists took measurements of trace gases in the atmosphere and surface seawater.

After departing Manzanillo, Dr. Spiess directed a comprehensive Deep Tow survey on the East Pacific Rise at 21°N. Indomed Leg 16 became a multiship operation of the RISE Program, a joint American, Mexican, and French study. R/V *New Horizon,* Scripps's newest ship, and R/V *Lulu* and submersible *Alvin* operated by Woods Hole Oceanographic Institution (WHOI), Massachusetts, joined the expedition. Scientists on the RISE Program carried out detailed sea floor geophysical studies, extended geological observations, and sampled areas previously mapped at the East Pacific Rise crest in the vicinity of 21°N, and investigated sulfide mounds discovered in 1977. Spectacular results, described elsewhere in this report, were obtained.

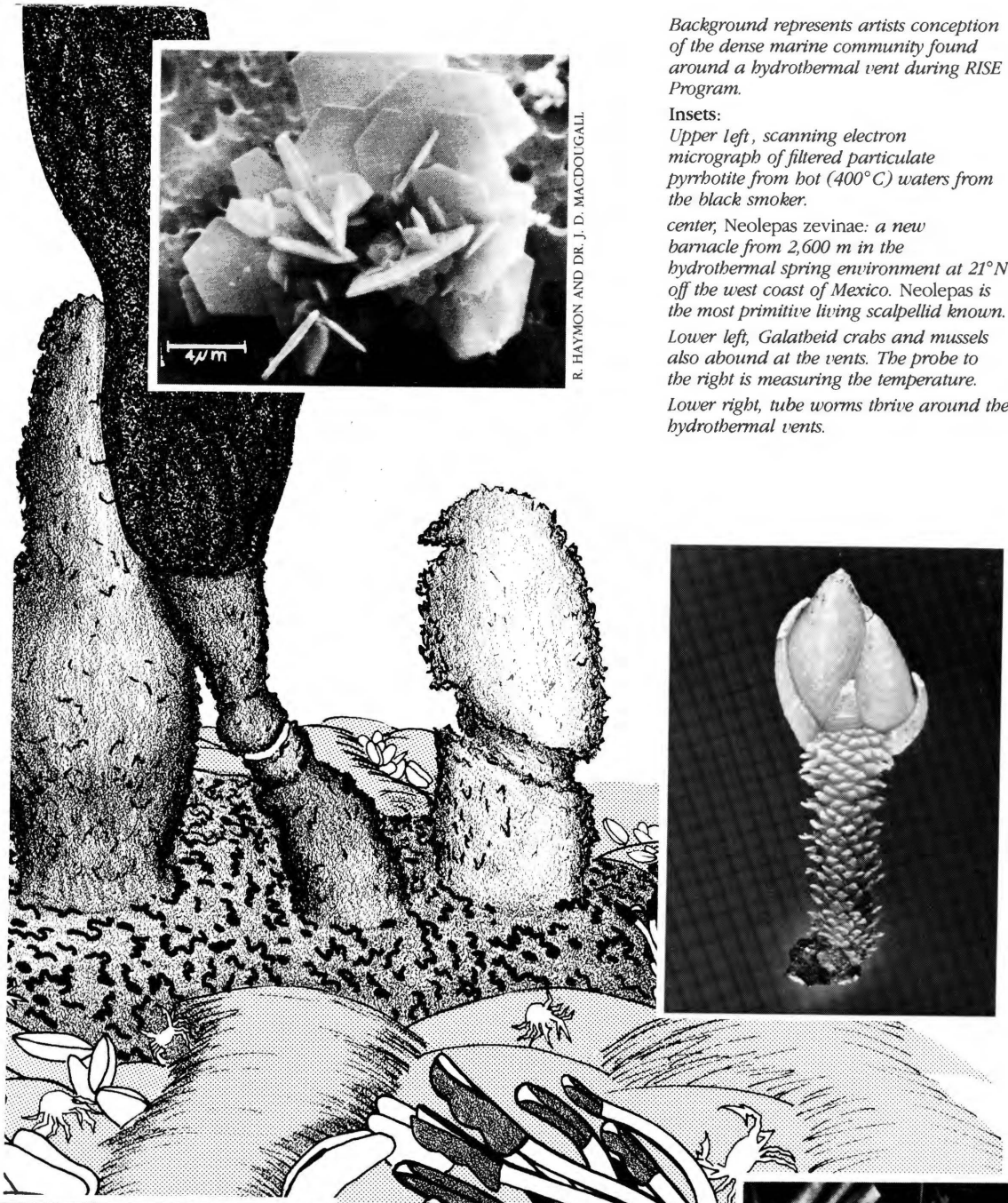
Melville reached San Diego on April 29, after 302 days at sea and 35,528 nautical miles. Indomed Expedition ended in fiscal year 1979. It was Scripps's second longest expedition in terms of distance steamed, 76,500 nautical miles, and lasted a record 19 months. After a short GEOSECS (Geochemical Ocean Sections Study) calibration/debriefing cruise under Dr. Harmon Craig, *Melville* was placed on inactive status for the remainder of the year.

On October 21, 1978, following builder's sea trials, R/V *New Horizon* was turned over to Scripps, and on November 1 she departed Jacksonville, Florida, for the Pacific coast with stops at Miami, Florida, and Balboa. She arrived in Ensenada, Mexico, late in November after a rough passage through the Gulf of Tehuantepec. After several short cruises out of Ensenada to test equipment, *New Horizon* arrived in San Diego on January 23. In a dedication ceremony at Scripps's Nimitz Marine Facility two days later, Judith Horton Munk was the sponsor and Governor Roberto de la Madrid Romandia of Baja California del Norte was guest speaker.

Judith Horton Munk christens R/V New Horizon *as her husband, Dr. Walter H. Munk, middle, and* New Horizon *captain, Laurence E. Davis, right, look on.*

After inclining tests, *New Horizon* departed San Diego for a 17-day southern California borderland cruise with Roswell W. Austin as chief scientist. Scientists conducted satellite ground truth optical and biological studies of near-surface waters. Dr. Peter M. Williams took *New Horizon* south into the Gulf of California and to Mazatlán, Mexico, to observe and measure surface film formation rates. From Mazatlán, Dr. Rodolfo Batiza, Washington University, St. Louis, Missouri, made dredge hauls at geologically Recent volcanics on the East Pacific Rise southeast of Clipperton Island. After recovering several ocean bottom instruments off Mazatlán for Dr. Jean H. Filloux, *New Horizon* joined RISE Program. During this program, Dr. Kenneth C. Macdonald's group made geophysical observations that included heat flow, cores, and 3.5 kHz profiling. After completing these observations, *New Horizon* arrived in San Diego in mid-May. Two short cruises and a shipyard maintenance period finished out the fiscal year. She was at sea for 110 days and covered 14,778 nautical miles.

R/V *Thomas Washington* departed San Diego late in July with Robert C. Wilson in charge, to commence Mariana Expedition, making bathymetric and magnetic observations en route to Honolulu. After a Honolulu-Honolulu benthic respiratory biological



ALEXES WALSER

R. HAYMON AND DR. J. D. MACDOUGALL

Background represents artists conception of the dense marine community found around a hydrothermal vent during RISE Program.

Insets:

Upper left, scanning electron micrograph of filtered particulate pyrrhotite from hot (400°C) waters from the black smoker.

center, Neolepas zevinae*: a new barnacle from 2,600 m in the hydrothermal spring environment at 21°N off the west coast of Mexico.* Neolepas *is the most primitive living scalpellid known.*

Lower left, Galatheid crabs and mussels also abound at the vents. The probe to the right is measuring the temperature.

Lower right, tube worms thrive around the hydrothermal vents.

DR. R. R. HESSLER

DR. F. N. SPIESS

investigation under Dr. Kenneth L. Smith, Jr.; *Thomas Washington* sailed for Guam, with depth profiling and magnetometer studies directed by graduate student Michael L. Van Woert. Two trench/basin geological/geophysical legs were made from Guam, one under Dr. Daniel E. Karig, Cornell University, Ithaca, New York, and one with Dr. Roger D. Anderson, Lamont-Doherty Geological Observatory, Palisades, New York. These legs were followed by a hadal amphipod trapping cruise in the Mariana Trench under the direction of Dr. A. Aristides Yayanos. After Christmas in Apra, Guam, *Thomas Washington* left on January 4, 1979, on a multichannel seismic reflection geophysical cruise headed by Dr. Eli A. Silver, UC Santa Cruz. This cruise, via the basins and passages of the Molucca and Banda seas, ended in Jakarta, Indonesia. After another seismic reflection and sonobuoy investigation leg, led by Dr. George G. Shor, Jr., this time on the Ninetyeast Ridge and in the Andaman Sea, *Thomas Washington* was placed on lay-up and refurbishment status in Guam for the remaining quarter of the year. During fiscal 1979, *Thomas Washington* was under way for 226 days and sailed 29,034 nautical miles.

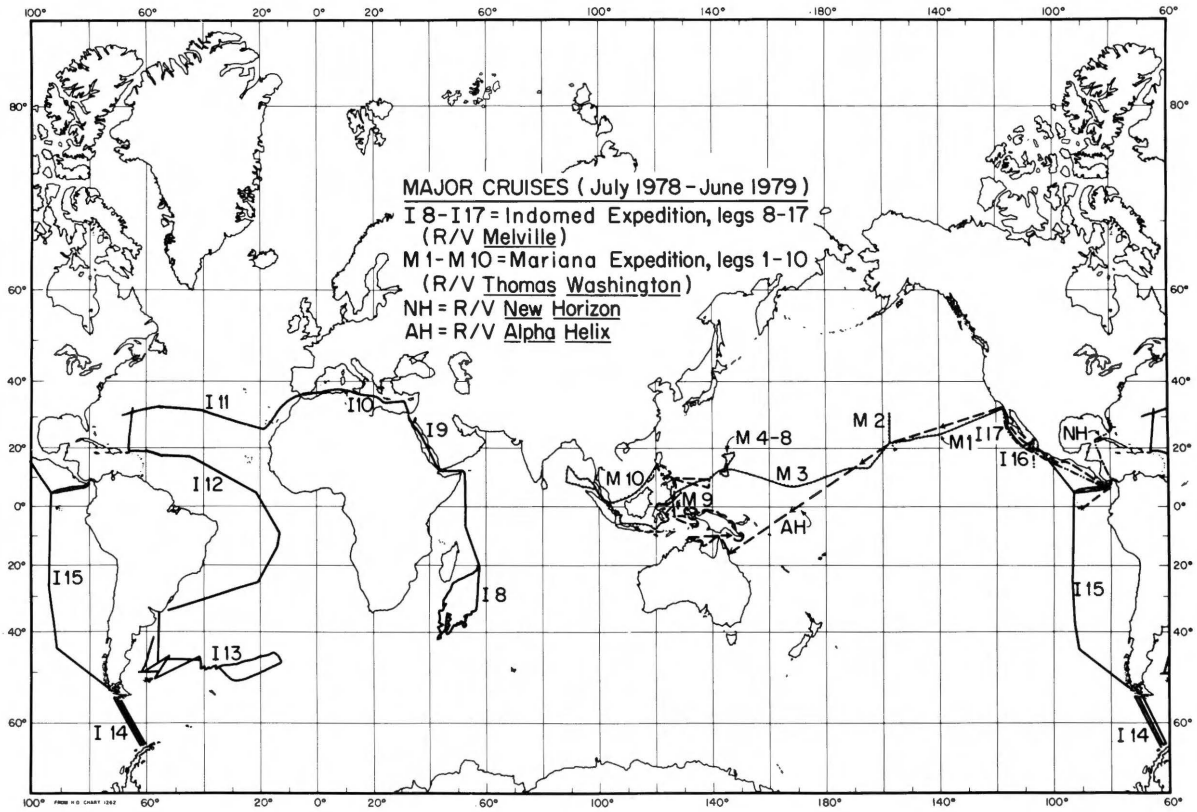
Alpha Helix started the fiscal year on a 50-day operation to study the physiology of the marine iguana in the Galápagos Islands, under the leadership of Dr. George A. Bartholomew, UCLA. The next part of her Caribbean/Pacific Expedition took *Alpha Helix* off the east coasts of Costa Rica and Nicaragua to study the respiratory and circulatory physiology, energetics, temperature regulation, and behavior of the green turtle, with Dr. Henry D. Prange, University of Indiana, Bloomington, as chief scientist. Dr. Abraham Fleminger then brought *Alpha Helix* to San Diego, sampling zooplankton on station profiles in the nearshore waters off Mexico in a joint program with Mexican investigators who boarded at Salina Cruz. *Alpha Helix* was placed on inactive status and underwent biennial overhaul from mid-October until the end of February 1979. On March 2 she sailed for Cairns, Australia, on Moro Expedition, under the command of Captain Robert B. Haines. The first intensive scientific work of Moro Expedition took place near Thursday Island in Torres Strait, where Dr. Patrick L. Parker, University of Texas, Port Aransas, directed studies of the eel grass ecosystems to complement those made from *Alpha Helix* the previous year in the western Caribbean. A follow-up month of similar studies, led by Dr. Peter C. McRoy, University of Alaska, College, ended in Darwin, Australia, late in May. Dr. Fleminger headed a near-circumnavigation of New Guinea from Darwin to Ambon, Indonesia, and thence to Cebu City in the southern Philippines to carry out nearshore samplings of zooplankton for biogeographical distribution. At several shore and nearshore sites mollusc and crustacean collections were made by Dr. Geerat J. Vermeij, University of Maryland, College Park. *Alpha Helix* arrived in Cebu City on the 24th of July to prepare for the imminent coconut crab program in the Palau Islands. *Alpha Helix* was at sea 217 days during the fiscal year and steamed 19,076 nautical miles.

Ellen B. Scripps, Scripps Institution's smallest seagoing vessel, made 49 sorties, ranging from 1 to 13 days, during fiscal 1979. Programs covered all disciplines, with emphasis on acoustic research, bottom seismometer geophysics, and biological oceanography. Shorter trips were principally for student training and research, as well as equipment development and deployment. Most of the users were Scripps staff and students, but others were from various southern California universities. In operations ranging from Monterey Bay to the Gulf of California, *Ellen B. Scripps* logged 146 days at sea and steamed 11,976 nautical miles.

R/P FLIP made four trips for the Marine Physical Laboratory during the fiscal year. These ranged 3-11 days at sea, and totaled 34 days as FLIP was towed 1,440 nautical miles. Dr. Robert Pinkel conducted trips to measure internal waves and test equipment. Dr. Robert C. Tyce conducted data acquisition and vertical array work and tests. The research platform ORB made one 6-day, 66-nautical-mile test trip in conjunction with the submersible acoustic array (ADA).

Visiting Vessels

Nimitz Marine Facility occasionally provides berthing and logistic support to oceanographic research vessels from sister U. S. or foreign scientific institutions or agencies that are engaged in collaborative research. During fiscal 1979, these included: *Thomas G. Thompson,* University of Washington, Seattle; *Sea Watch,* University of Southern California, Los Angeles; *Sea Sounder,* U. S. Geological Survey, Menlo Park, California; *Scorpius,* National Marine Fisheries Service; T/B *Auguste Piccard,* a bathyscaphe, Gulf Maritime Inc.; *David Starr Jordan,* National Oceanic and Atmospheric Administration; *Alvin,* a deep research submersible and her tender *Lulu,* WHOI.

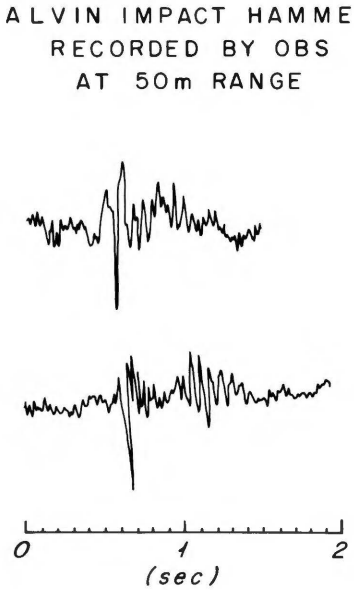


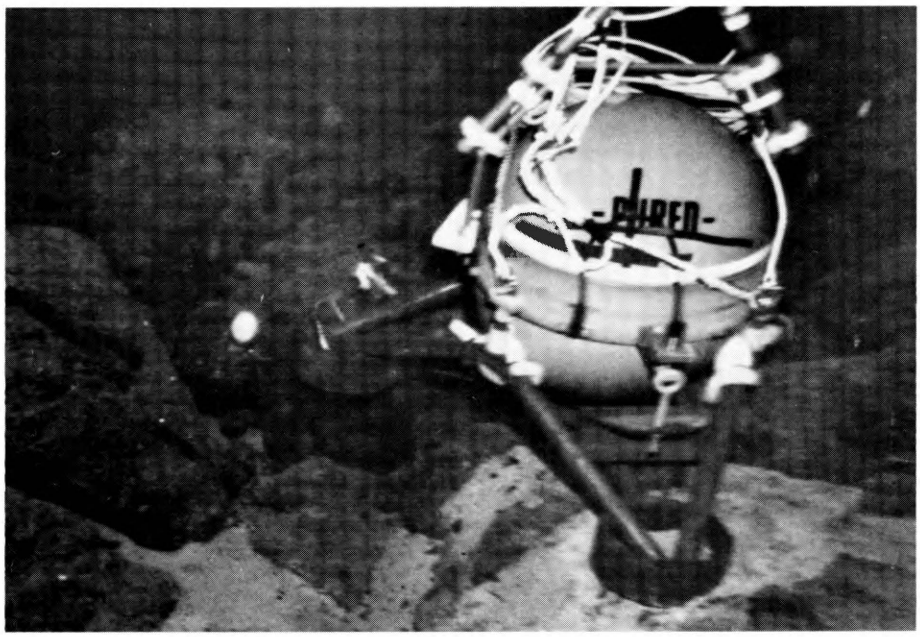
Track Chart

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. Ship-building 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:	40.53 m	74.67 m	51.81 m	28.95 m	63.70 m	108.20 m	21.03 m
Beam:	9.44 m	14.02 m	10.97 m	7.31 m	12.00 m	6.09 m	13.71 m
Draft:	3.18 m	4.87 m	3.65 m	1.82 m	4.39 m	3.35/91.44 m	fwd. 1.48 m aft 1.63 m
Displacement, full (metric tons):	464	1,882	698	212	1,235	1,359	294
Cruising speed (knots):	10	10	10.5	9	11	varies[-1]	varies[-1]
Range (nautical 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	20	12	5	19	6	5
Scientific party:	12	30	13	8	23	10	10

[-1]Depends upon towing vessel
1978-79 Total days at sea: 1,041
1978-79 Nautical miles steamed: 111,898





DRS. J. A. ORCUTT AND K. C. MACDONALD

Two impact hammer seismograms recorded by an ocean bottom seismograph at 50 m range, left, and one element of the ocean bottom seismograph array on the sea floor at 2,610 m. A near surface in situ crustal velocity of 3.3 km sec^{-1} was determined from this station.

GRADUATE DEPARTMENT

The Graduate Department of the Scripps Institution of Oceanography offers instruction leading to Ph.D. degrees in oceanography, marine biology, and earth sciences. Because of the interdisciplinary nature of the ocean sciences, the department provides the student with a choice of seven curricular programs through which he may pursue his five year Ph.D. degree. Each of these curricular groups has requirements for admission in addition to the departmental requirements. The curricular programs are described below. For admission requirements and more information, please write to: Graduate Department, A-008, Scripps Institution of Oceanography, La Jolla, California 92093.

Applied Ocean Sciences. Interdepartmental in nature, this curriculum combines the resources of the Scripps graduate department and the Department of Applied Mechanics and Engineering Sciences and the Department of Electrical Engineering and Computer Sciences, on the UC San Diego campus. Engineers are provided a substantial education in oceanography and oceanographers receive training in modern engineering. The instruction and basic research include structural, mechanical, material, electrical, and physiological problems operating within the ocean, and the applied science of the sea.

Biological Oceanography. 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 range from food-chain dynamics and community structure to taxonomy and zoogeography of oceanic organisms.

Geophysics. This curriculum is designed to educate the physicist (theoretician or experimentalist) to understand 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.

Marine Biology. The marine biology curriculum places particular emphasis on the biology of marine organisms—animals, plants, and prokaryotes. The research and teaching encompass a range of biological disciplines, including behavior, neurobiology, developmental biology, and comparative physiology/biochemistry.

Marine Chemistry. 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.

Geological Sciences. 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. 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; tides; the propagation of sound and electromagnetic energy in the ocean; and the properties and propagation of ocean waves.

Dr. Richard H. Rosenblatt teaches a class in fish biology.

GRADUATE STUDENTS AND DEGREE RECIPIENTS

In the fall of 1978, 28 new students were admitted to graduate study. Of these, 10 were in marine biology, 4 in geological sciences, 5 in marine chemistry, 3 in geophysics, 2 in physical oceanography, and 4 in applied ocean sciences. Enrollment at the beginning of the academic year was 180. Ten Master of Science degrees and 20 Doctor of Philosophy degrees were awarded by UC San Diego to the students listed below:

Doctor of Philosophy Degrees Awarded with Titles of Dissertations

Earth Sciences

Jan D. Garmany, "Methods of Seismic Travel Time Calculation and Inversion and of Synthesizing High Frequency Seismograms."

Stephen H. Hartzell, "Interpretation of Earthquake Strong Ground Motion and Implications for Earthquake Mechanism."

Stuart A. Sipkin, "Constraints on Earth Structure Determined from Observations of Multiple ScS."

Paul A. Spudich, "Oceanic Crustal Studies Using Waveform Analysis and Shear Waves."

Marine Biology

Robert D. Bowlus, "Solute Compatibility with Biological Macromolecules: The Influence of the Major Intracellular Solutes of Marine Invertebrates on Enzyme Structure and Function."

Paul H. Yancey, "Urea, Trimethylamine Oxide, and pH: Adaptive Interactions Among Enzymes and Intracellular Solutes in Elasmobranchs and Other Vertebrates."

Oceanography

Tarsicio Antezana-Jeréz, "Distribution of Euphausiids in the Chile-Peru Current with Particular Reference to the Endemic *Euphausia mucronata* and the Oxygen Minima Layer."

Thomas L. Hayward, "Spatial and Temporal Patterns of Feeding of Oceanic Copepods."

Bruce M. Howard, "The Natural Products Chemistry of the Marine Red Algal Genus *Laurencia* Lamouroux."

Robert S. Howard, "Pragmatic Approaches to Shallow-Water Decompression Studies."

Valerie J. Loeb, "The Ichthyoplankton Assemblage of the North Pacific Central Gyre: Spatial and Temporal Patterns."

Larry A. Mayer, "The Origin and Geologic Setting of High Frequency Acoustic Reflectors in Deep-Sea Carbonates."

Oliver J. McConnell, "Chemical and Biochemical Studies of the Halogenating Red Algae *Asparagopsis* and *Bonnemaisonia*."

Russell E. McDuff, "Conservative Behavior of Calcium and Magnesium in the Interstitial Waters of Marine Sediments: Identification and Interpretation."

Philip M. Shou, "Kinetics and Mechanisms of Several Amino Acid Diagenetic Reactions in Aqueous Solutions and in Fossils."

Glenn R. VanBlaricom, "Disturbance, Predation, and Resource Allocation in a High-Energy Sublittoral Sand-Bottom Ecosystem: Experimental Analyses of Critical Structuring Processes for the Infaunal Community."

Victor M. V. Vidal L., "Studies of Marine Hydrothermal Activity in a Coastal Environment—Punta Banda, Baja California Norte, Mexico—and its Geochemical Implications for Modelling Marine Hydrothermal Processes in the Ocean."

Caroline S. Weiler, "Phased Cell Division in the Dinoflagellate Genus *Ceratium:* Temporal Pattern, Use in Determining Growth Rates, and Ecological Implications."

Robert A. Weller, "Observations of Horizontal Velocity in the Upper Ocean Made with a New Vector Measuring Current Meter."

Karen F. Wishner, "The Biomass and Ecology of the Deep-Sea Benthopelagic (Near-Bottom) Plankton."

Master of Science Degrees

Earth Sciences

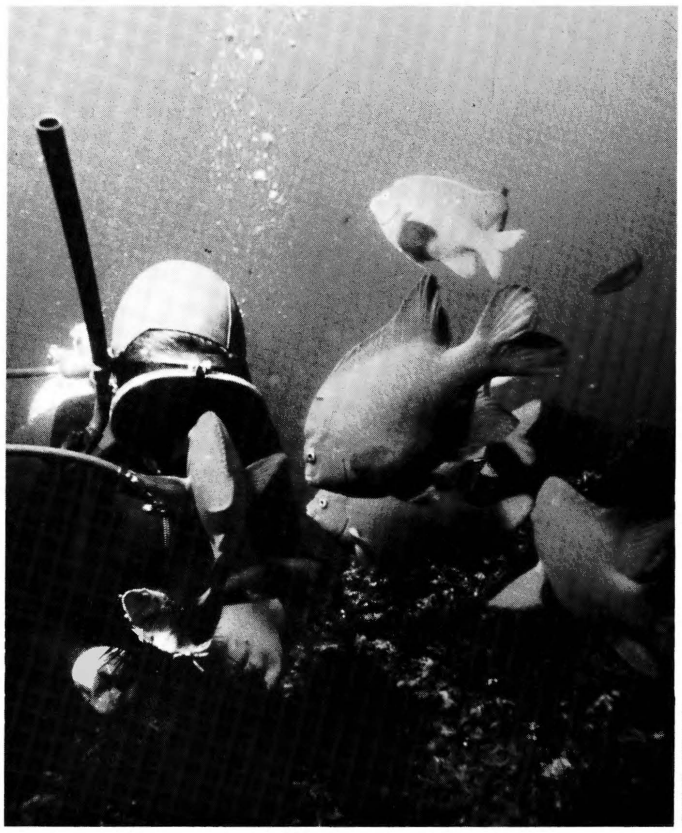
Alena L. Leeds

Marine Biology

Janis L. Hastings

Oceanography

Donald B. Altman
Douglas A. Coats
Daniel M. Hanes
Sean Killeen
Douglas E. McIntyre
David W. Skelly
Loren B. Smith
Sonja J. Walawender



CHUCK NICKLIN

SHORE FACILITIES AND SPECIAL COLLECTIONS

Facilities

Thomas Wayland Vaughan Aquarium-Museum. The aquarium-museum helps increase public understanding and appreciation of the ocean through exhibits of living marine animals, museum displays, and a variety of educational programs.

Research at the aquarium-museum is done on marine animal maintenance systems, fish coloration, and fish diseases. Through its collecting facility, several thousand specimens are supplied each year to Scripps scientists.

This year more than 47,000 students in educational groups toured the aquarium-museum. It is open to the public daily; admission is free.

Analytical Facility. Instruments at 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 mini-computer for data handling; carbon-dioxide analyzer, and a Cambridge S-4 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 ultrafine 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. This shared facility of the Physiological Research Laboratory and the UC San Diego School of Medicine consists of an experimental animal colony, equipment for physiological research that involves measurements of circulatory and cardiac functions in free-moving animals, and a cardiovascular instrumentation development laboratory.

Diving Facility. The diving program is housed in two separate facilities. One contains the mechanical gear of the program and 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 Scripps scientists and technicians. There are currently 130 Scripps faculty, staff, and students who dive in all the oceans of the world, including the Antarctic.

Experimental Aquarium. Used by faculty, research staff, and graduate students for 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. This laboratory has a wind-wave channel 43x2.4x2.4 m in size with a simulated beach and a tow cart for instrument and model towing; a 15x18-m wave-and-tidal basin with an adjustable simulated beach; a 40-m glass-walled, wave-and-current channel; a granular fluid mechanics test facility that consists 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 that belong 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.

Marine Science Development and Outfitting Shop. 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 and other educational and governmental organizations throughout the United States.

Mass Spectrographic Equipment. 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.

Petrological Laboratory. 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.

Physiological Research Laboratory Pool Facility. This facility includes a holding pool for large marine mammals and fish; a ring pool of 10-m radius equipped with a variable-speed trolley to carry 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.

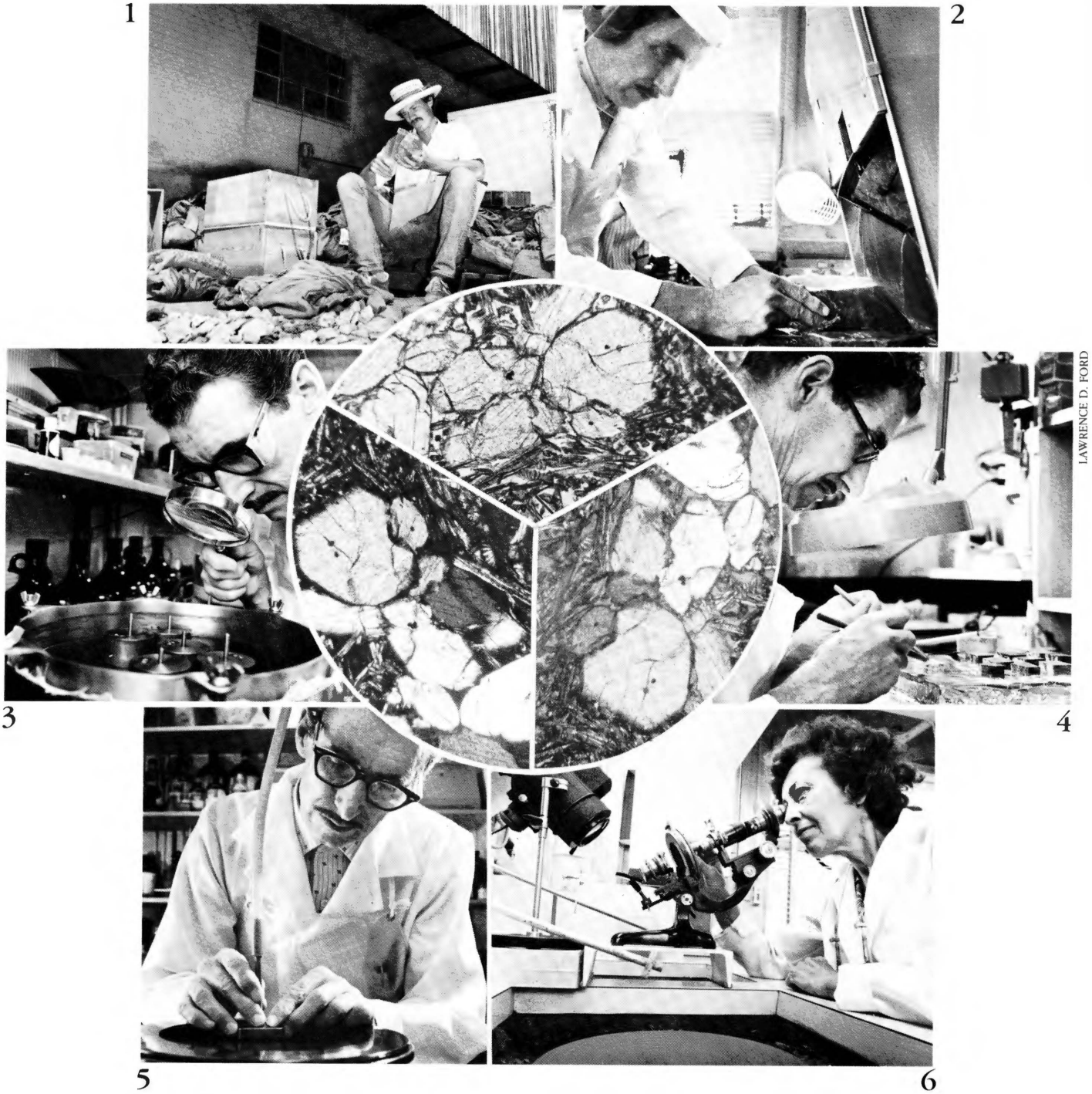
Radio Station WWD. Licensed to the National Marine Fisheries Service and operated by personnel from Scripps's Nimitz Marine Facility, station WWD provides communications services to both organizations and to other governmental and institutional ships. Weather advisories are provided routinely to the fishing fleet as well as to scientific vessels.

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. The library's collections in oceanography, marine biology, and undersea technology complement its store of oceanographic information. The 130,000 bound volumes include 6,600 serial titles and extensive expedition literature. The Documents/Reports/Translations Collection is comprised 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 emphasizes nautical information, and is a depository for U.S. Geological Survey geologic maps and related publications. The library's Rare Book Collection includes numerous accounts and journals of famous voyages of discovery.

Scripps Pier. The 305-m pier serves as a launching site for small boats utilized to conduct local oceanographic work and provides space for on-site observational studies.

Seawater System. Pumps located on Scripps Pier deliver seawater to the laboratories and aquaria of Scripps and the Southwest



A geologic sample from the Mariana Expedition goes through many steps before Dr. James W. Hawkins receives it as a thin-section for study in his laboratory.

1. *Graduate student Sherman H. Bloomer sorts the samples brought back from the Mariana Expedition.*

2. *Roy M. De Haven slices one of the rocks to prepare it for thin-sectioning in the Petrological Laboratory.*

3. *Polishing of probe slides for the electron microscope is checked by De Haven.*

4. *Slides are glued to sample before the surplus is cut off.*

5. *Slide undergoes preliminary hand polishing on diamond paste.*

6. *Betty J. De Haven gives the thin section a final check before it leaves the Petrological Laboratory.*

Center, *micrograph of thin section as viewed under three types of light.*

Fisheries Center. The seawater system utilizes two high-speed sand filters and two concrete storage tanks with a total capacity of 439,060 ℓ. Delivery capacity is 5,300 ℓ per minute.

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

The IBM 1800 computer systems 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 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.

A Prime 500 computer system on campus is well adapted to economical number-crunching with a 6.5 μs floating point (64 bits) multiplier, one megabyte of memory, and 600 megabytes of disk. Its use is primarily by CRT terminals.

Underwater Research Areas include:

Scripps Shoreline Reserve. Scripps Shoreline Reserve consists of a 100-acre tract of seashore and ocean where marine plants and invertebrates are protected for research purposes and may be collected only with permits.

Scripps Submerged Land Area. This area is leased by the University of California from the city of San Diego. The 640 acres extends seaward and to the north of Scripps.

Ecological Reserve. The 580-acre San Diego-La Jolla Ecological Reserve was established primarily for conservation and is protected from any collecting. It has shown measurable return to its original pristine condition.

Collections

Benthic Invertebrates. 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% are identified according to species. Specimens are available for study to qualified students and researchers.

Deep Sea Drilling Project Core Repository. Scripps houses the West Cost Repository for cores collected by DSDP from the Pacific and Indian oceans. Core samples are made available to qualified researchers throughout the world under policies established by the National Science Foundation.

Geological Core Locker. This core locker contains a collection of several thousand deep-sea sediment cores kept under refrigeration and bulk assemblages of rocks and manganese nodules collected by dredging from the major ocean basins. These materials are available to any scientific investigator or student.

Geological Data Center. Most of the geological/geophysical data collected by Scripps vessels while under way are processed and archived at this location. Navigation, depth, and magnetics data 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. A small herbarium of marine benthic algae is comprised of specimens from the U.S. Pacific coast, chiefly from the San Diego area, or collected during Scripps expeditions in the Pacific Ocean. There are some 1,600 sheets of pressed seaweeds, identified and arranged in taxonomic order. The specimens, although primarily used for teaching, are available for consultation by any botanist or interested student.

Marine Invertebrates. In this collection of documented whole zooplankton samples are also sorted specimens and identified collections of major taxonomic groups, which include the adult cephalopoda. Most samples are supplemented by meteorological, hydrographic, physical, and chemical data.

Marine Vertebrates. This collection contains more than two million specimens, with 3,200 cataloged species, including 128 primary types. Approximately 500 collections are added each year. Although the collection is worldwide, it specializes in deep-sea and eastern Pacific shore fishes. It contains large holdings of shore fishes from the Gulf of California and Panama and an extensive skeletal collection of both dried preparations and cleared-and-stained specimens in glycerin.

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 forwarded to: Chief of the Datums and Information Branch, James R. Hubbard, C-233, NOAA/NOS, 6001 Executive Blvd., Rockville, MD 20852.

Temperature and salinity records, taken daily, 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 Physical and Chemical Oceanographic Data Facility.

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.

PUBLICATIONS

Introduction

The results of the research done at Scripps are published in many different forms that range from short contractual reports to long taxonomic descriptions. Scripps publications are distributed by subscription, exchange, or government contract.

Below is a complete listing of the SIO Publications for fiscal 1979. Detailed availability information is included for each series.

Bulletin

The *Bulletin of Scripps Institution of Oceanography* is an irregularly published series for lengthy, in-depth scientific papers written by the faculty and staff. 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.

CalCOFI Atlas Series

The *California Cooperative Oceanic Fisheries Investigations* (CalCOFI) *Atlas Series* provides processed physical, chemical, and biological measurements of the California Current region. The series reflects the work of the CalCOFI program, sponsored by the state of California under the direction of the state's Marine Research Committee, of which Scripps is one of five cooperating agencies.

These atlases are distributed at no charge to research institutions, university libraries, and qualified research scientists active in oceanographic fields relating to the CalCOFI program. Editions are limited to 650 copies. Those institutions or libraries interested in acquiring atlases should write to: Dr. Abraham Fleminger, Scripps Institution Of Oceanography, A-001, La Jolla, California 92093.

The atlas issued this year is listed below.

No. 26 **Ahlstrom**, Elbert H., H. Geoffrey **Moser** and Elaine M. **Sandknop**. Distributional atlas of fish larvae in the California Current region: Rockfishes, *Sebastes* spp., 1950 through 1975. June 1978. 197p.

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-075a, La Jolla, California 92093.

The articles listed below may be found in the publications cited. Information about a specific reprint may be obtained by writing directly to the author in care of: Scripps Institution of Oceanography, La Jolla, California 92093.

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Arnold E. Bainbridge

Arnold E. Bainbridge. February 27, 1979. He was director of the Physical and Chemical Oceanographic Data Facility and an academic administrator. He joined the Scripps staff in 1966 and was instrumental in establishing GEOSECS (Geochemical Ocean Sections Study). He was the designer of systems for acquiring and reducing chemical and physical oceanographic data and was a pioneer in use of tritium in problems of oceanic circulation.

William C. Bartram. November 21, 1979. He was a graduate student in biological oceanography. He had been at Scripps for six years.

John W. Bonham. January 9, 1979. He was a senior captain (retired) at Nimitz Marine Facility. He started work at Scripps in 1962.

Barbara A. Edwards. May 3, 1979. She began work at Scripps in 1956 and had been a secretary in the Ocean Research Division.

Trudy K. Hey. September 20, 1978. She was a laboratory assistant in the Ocean Research Division, who began work at Scripps in 1967.

Morris E. "Scotty" Horn. September 29, 1978. He was a first officer at the Nimitz Marine Facility. He started work at Scripps in 1958.


Dr. Carl L. Hubbs

Carl L. Hubbs. June 30, 1979. He was professor of biology from 1944 and emeritus in 1962. His research included taxonomy and behavior of fishes, ecology, marine mammals, and archeology. He was a member of the National Academy of Sciences and had had 5 genera and more than 20 species of fishes named in his honor. By bequest, Dr. Hubbs's extensive personal library and files of notes will become a special collection in the Scripps Library.

Derek Wildman. September 27, 1978. He began at Nimitz Marine Facility in 1978 as an oiler.

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*Anyone interested in making a donation to the institution should contact the Scripps Director's Office, A-010, Scripps Institution of Oceanography, La Jolla, CA 92093.

APPENDIX C

Major Awards and Honors

Dr. Wolfgang H. Berger
Received the Henry Bryant Bigelow Award in Oceanography from Woods Hole Oceanographic Institution.
Dr. Ralph J. Cicerone
Received the James B. Macelwane Award from the American Geophysical Union.
Dr. Harmon Craig
Elected to Membership in the National Academy of Sciences.
Dr. Carl L. Hubbs
Received Outstanding Achievement in Fisheries Award from the Arizona-New Mexico Chapter of the American Fisheries Society. Elected President for Life of the Asociación Mexicana para el Estudio de los Mamiferos Marinos, A. C.
John D. Isaacs
Received highest award from the Sea Grant Association.
Dr. Devendra Lal
Elected a Fellow of the Royal Society of London.
Dr. Ralph A. Lewin
Appointed a member of NASA's Planetary Biology Advisory Panel.
Dr. John W. Miles
Elected to Membership in the National Academy of Sciences.
Dr. Walter H. Munk
Received the Capt. Robert Dexter Conrad Award from the U.S. Navy.
Dr. Jerome Namias
Received Headliner Award in Science from the San Diego Press Club.
Dr. William A. Nierenberg
Selected to present the American Association of Physics Teachers' annual Richtmyer Memorial Lecture. Elected to the Council of the National Academy of Sciences. Received the San Diego Cabrillo Festival's Cabrillo Award of Excellence for Affairs of the Sea.
Dr. Francis P. Shepard
Received the first Sorby Medal from the International Association of Sedimentologists.

APPENDIX D

The Regents of the University of California

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Leo T. McCarthy
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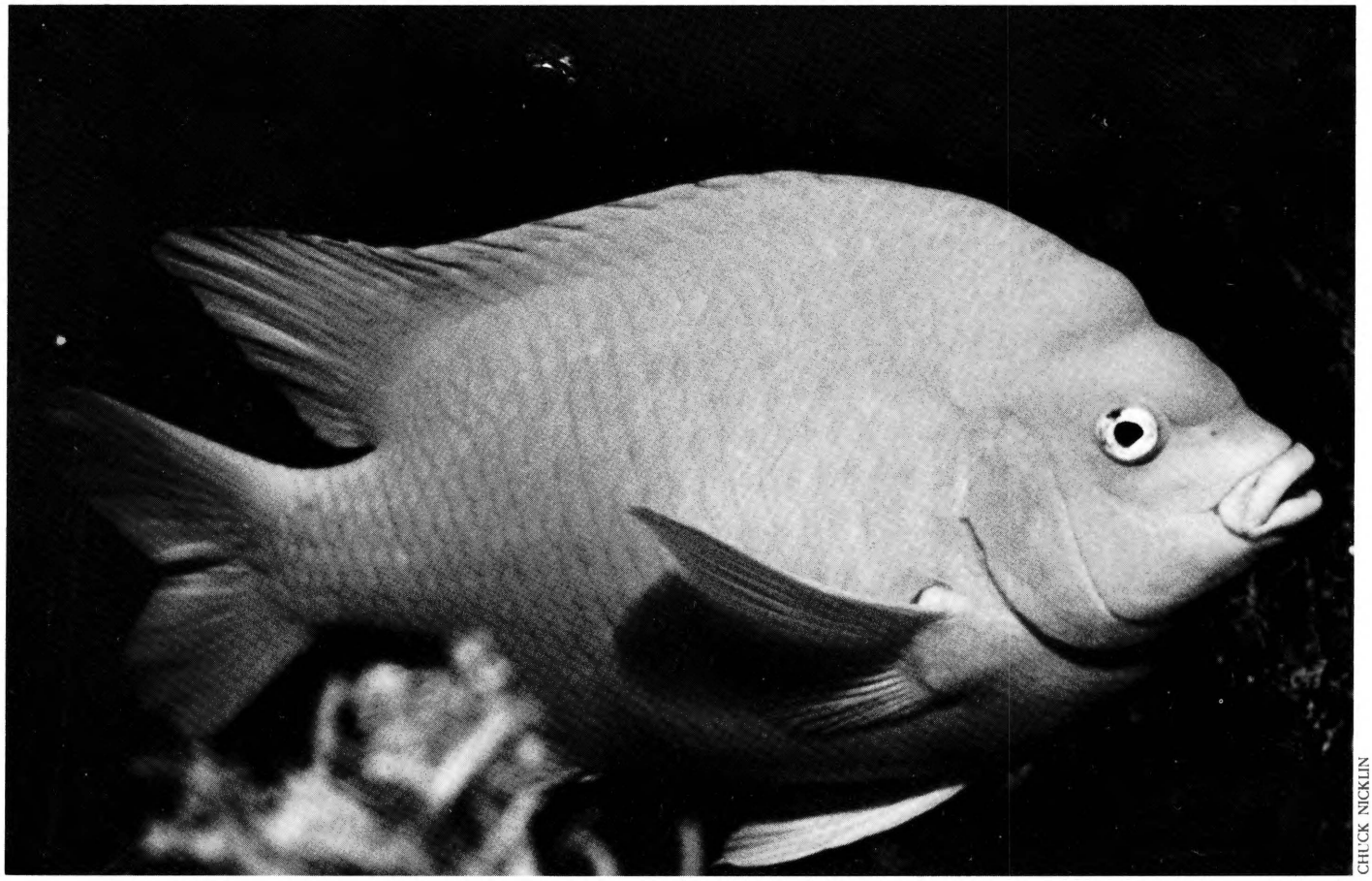
APPENDIX E

Current Funds Expenditures 1978-1979

INSTITUTES

Agency	Scripps Institution of Oceanography	Geophysics and Planetary Physics	Marine Resources	Total	Percentage of Total
FEDERAL GOVERNMENT					
National Science Foundation	$24,937,648	575,055	359,754	25,872,457	56.5
Navy, Department of the	5,268,401	535,950	87,224	5,891,575	12.9
National Oceanic and Atmospheric Administration	11,927	—	1,271,390	1,283,317	2.8
Energy, Department of	180,644	74,277	493,393	748,314	1.6
Air Force, Department of the	534,211	640	87,668	622,519	1.4
National Institutes of Health	363,669	—	21	363,690	0.8
National Aeronautics and Space Administration	144,344	101,096	—	245,440	0.5
Other	1,099,067	154,823	36,496	1,290,386	2.8
Total Federal Government	32,539,911	1,441,841	2,335,946	36,317,698	79.3
STATE AND UNIVERSITY FUNDS	6,231,941	227,892	423,513	6,883,346	15.0
LOCAL GOVERNMENT	137,216	—	364,997	502,213	1.1
PRIVATE GIFTS AND GRANTS	1,917,954	66,322	113,456	2,097,732	4.6
ENDOWMENT FUNDS	18,129	—	2,133	20,262	—
MISC. SALES AND SERVICES	(53,347)	(2,982)	6,574	(49,755)	—
Total Current Funds Expenditures	$40,791,804	1,733,073	3,246,619	45,771,496	100.00



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Aerial view of Scripps.

All correspondence pertaining to this specific report should be directed to:
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