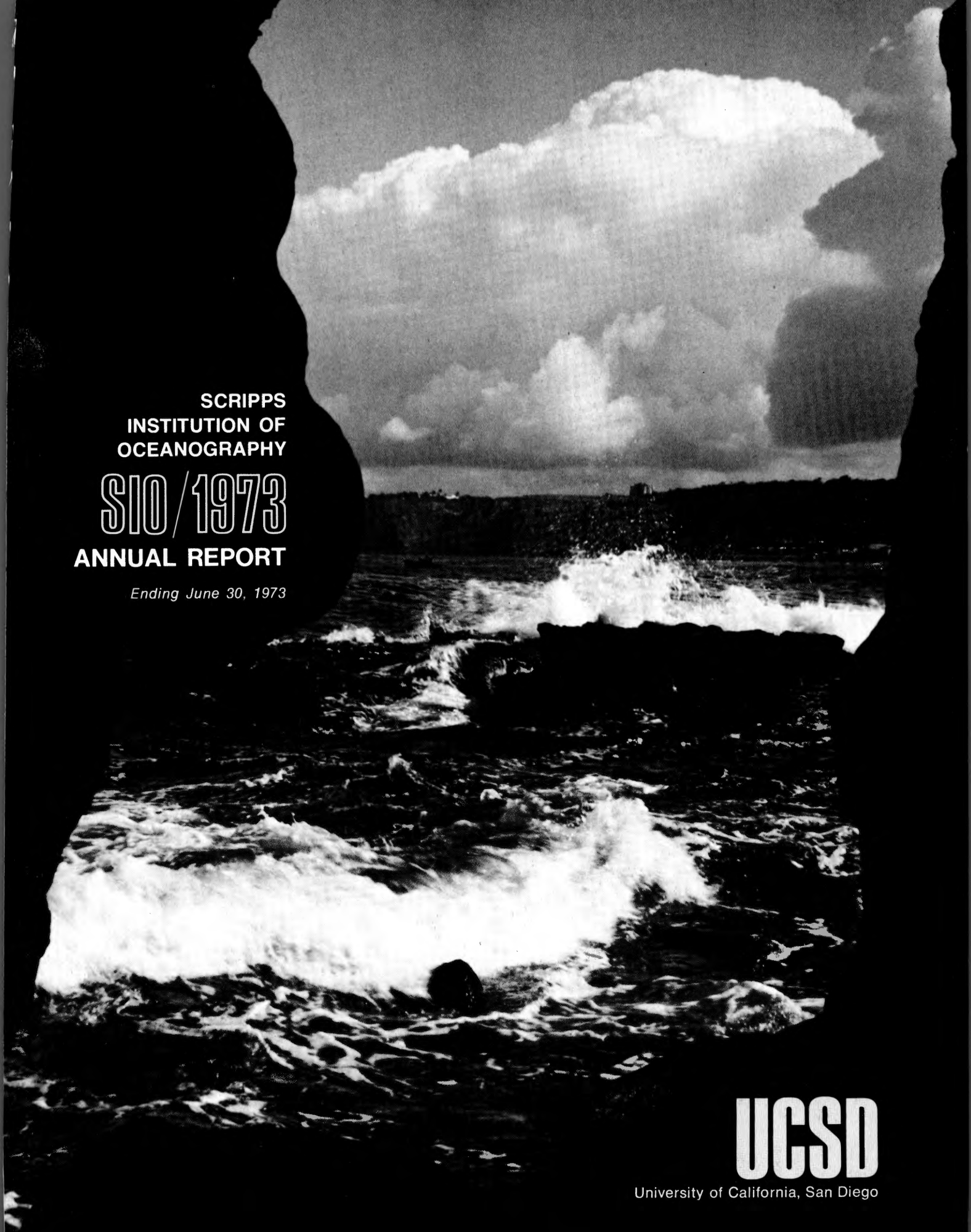

SCRIPPS INSTITUTION OF OCEANOGRAPHY

SIO/1973 ANNUAL REPORT

Ending June 30, 1973

UCSD

University of California, San Diego

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UNIVERSITY OF CALIFORNIA, SAN DIEGO

SCRIPPS INSTITUTION OF OCEANOGRAPHY

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ANNUAL REPORT

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No person affiliated with Scripps Institution of Oceanography has been on campus as long as Dr. Denis L. Fox, professor emeritus of marine biochemistry. Armed with his doctorate from Stanford and a baccalaureate from UC-Berkeley, he arrived here on September 1, 1931. Through the years, he has shared his expertise with researchers from around the world, including, above, in his laboratory, Dr. Wilbert K. Chagula, principal of University College at Dar-es-Salaam, Tanzania. Dr. Fox's characteristic smile reveals his penchant for storytelling and writing poetry, not to mention his pleasure in following the progress of his students after graduation.

Using the trident as a staff, this native son of Sussex, England, had the distinction of serving as grand marshal for the academic procession during several UC-San Diego commencement exercises, starting with the first graduating class of 1968.

Noted for his investigations into the coloration of flamingoes, Dr. Fox is recognized for his research in animal biochromes (pigments), the growth and metabolism of marine animals, colloidally particulate organic matter in marine waters and sediments, and biochemical fossils. For many years he has been a consultant to state, city, and industrial agencies on measures to counteract the fouling of underwater structures by marine animals.

Dr. Fox has been a Fellow of the San Diego Society of Natural History, dating back to 1931, and served as president of the Fellows in 1936. He has been a member of the San Diego Zoological Society Research Council since 1940, and was its chairman on more than one occasion.

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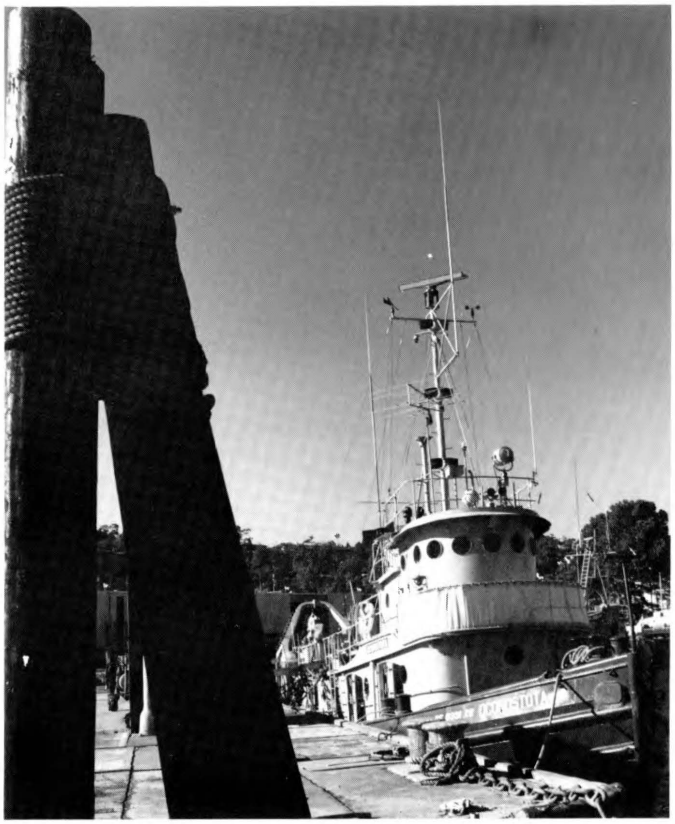
Published at Building 101, Lyman Avenue
Matthews Campus, University of California,
San Diego, La Jolla, California 92037
Volume 7, Number 5: July, 1974
A series of administrative publications of the University of California at San Diego, Post Office Box 109, La Jolla, California 92037
Second-class postage paid at La Jolla, California.
Five issues a Year:
April, May, June, July and August.
All announcements herein are subject to revision. Changes in the list of Officers of Administration may be made subsequent to date of publication.

A major fraction of the work reported herein was supported by the Office of Naval Research and the National Science Foundation.
Unless credited otherwise, photographs have been provided by the Photographic Laboratory of Scripps Institution of Oceanography.

Cover by Glasheen Graphics



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INTRODUCTION

Events at the Scripps Institution of Oceanography during 1972-73 have not been as exciting as those on the national and international scene, but we note a number here for the record and continuity.

International activity in particular has been especially interesting. An eight-man delegation of Russian oceanographers spent nearly a week at the Institution in December, 1972, during a U. S. tour of exchange. This was to return a September visit in the Soviet Union by a similar group of U. S. oceanographers. The visit to Scripps would not call for special mention, except that it led directly to an oceanographic agreement between the governments, signed in Washington the following June by the foreign secretaries of the two nations in the presence of President Nixon and Leonid I. Brezhnev, general secretary of the Communist party in the Soviet Union. This agreement established a joint committee in oceanography to define and carry out joint programs. A special feature of the agreement was the arrangement for participation by the Soviet Union in the Deep Sea Drilling Project, including a financial contribution.

In addition, a joint U.S.-U.S.S.R. Working Group on Cooperation in the Field of Effect of Pollutants on Marine Organisms held a three-day meeting on campus in May, 1973, that culminated in recommendations to the Joint Working Committee calling for expanded cooperation in the field, exchange of scientific teams in laboratory visits, and joint publications. Two members of the Scripps faculty were members of the Working Group: Professors Edward Goldberg and Claude ZoBell. Because of Professor ZoBell's illness at the time of the May visit by the Russian team, Professor Goldberg was a principal figure in the joint discussions.

A very important event was announced by Professor Walter Munk. This was the establishment of the La Jolla Foundation for Earth Sciences and the arrival of the first Cecil H. and Ida Green Scholar for Earth Sciences, Dr. Xavier T. LePichon, from CNEXO, the French National Center for Exploitation of the Oceans.

Another event that must not go unrecorded was the departure of Polly and Warren Wooster, who had been with the Institution since 1947. Professor Wooster was one of the most distinguished members of the Scripps family, with a record of unique accomplishment in the international field. We expect even more of him in his position as Dean of the Rosenstiel School of Marine and Atmospheric Science of the University of Miami.

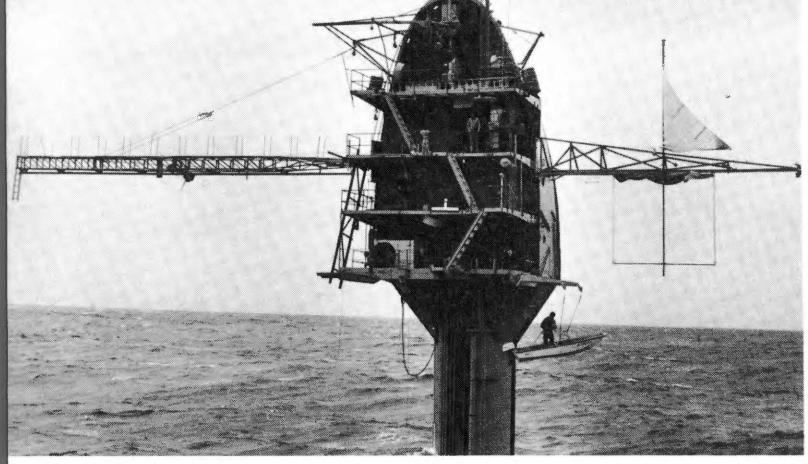
Regarding the Institution as a whole, it continues to prosper. Nevertheless, there will be a leveling off in activity for a few years, caused by the absorption of a variety of environmental programs and consequent adjustments. The next impact will arrive in the form of resource development that will be largely integrated with the environmental forerunner. This is a feedback effect, for many of the research programs related to the environment and resources that have occupied the laboratory for years are being reflected back in larger terms by the state and federal governments.

William A. Nierenberg

William A. Nierenberg, Director

Arthur Godfrey, radio and television personality, left, discusses the saving of the coastline, one of his environmental concerns, with Director Nierenberg during brief visit with scientists in the San Diego area.

Ted Winfield Photo, courtesy of SAN DIEGO UNION



R/P FLIP

R/P ORB

SEAGOING OPERATIONS

Nimitz Marine Facility and the Fleet

Scripps Institution of Oceanography operated seven research vessels during 1972-73: *George Melville, Thomas Washington, Alexander Agassiz, Alpha Helix, Oconostota, Ellen B. Scripps,* and *ST-908.* R/Vs *Melville, Washington,* and *Alpha Helix* were engaged in major expeditions, and the fleet spent 1,485 days at sea, and tracked 152,224 nautical miles during the year.

R/V *Melville* left San Diego June 7, 1972, on the eight-month Cato Expedition (*q.v.*) that concluded when the ship put back into Nimitz Marine Facility on February 14, 1973. From February 15 to May 21, the vessel underwent upkeep and repairs in preparation for the Pacific GEOSECS Expedition that was scheduled to begin in August. Meanwhile, Victor Vacquier was scientific leader on Leg I of the Bentheface cruise off the west coast of Mexico, a geological-geophysical program that began May 21. During the year, R/V *Melville* was at sea 270 days and she steamed some 31,150 nautical miles.

In July, 1972, R/V *Washington* was working on Leg VI of South-Tow Expedition (*q.v.*). The 13-leg expedition ended in San Diego on February 21, 1973, following which the *Washington* entered a shipyard for routine overhaul. On May 15, she made a pre-cruise shakedown run, conducting seismic work and echo-sounding and air-gun operations in anticipation of the upcoming Tasaday Expedition. The ship logged 273 days at sea, and covered 32,467 nautical miles.

The beginning of the year saw R/V *Alpha Helix* having replenished her supplies in Honolulu and en route to the Solomon Islands for the second phase of a 17-month expedition that had begun in San Diego February 28, 1972, and concluded at Nimitz Marine Facility June 16, 1973. A report on this cruise follows this section. The ship was at sea 351 days during the year, and logged 22,579 nautical miles.

R/V *Alexander Agassiz* was involved in routine CalCOFI cruises the first half of the year, and also spent two months in North Pacific waters on Climax IV research. Other work included a third CalCOFI cruise into the Gulf of California, and an extended trip along the west coast of Mexico, in addition to shorter trips off Southern California. The vessel spent 236 days at sea and steamed 31,300 nautical miles.

Work of R/V *Oconostota* included numerous short trips during the year on a wide variety of missions, including instrument tests, biological studies, seismic work, physical oceanography, and the towing of R/P ORB. In the latter part of the year, the ship took part in the Exito II cruise, to Guaymas and Topolobampo, Mexico, mainly for geological research. The vessel was at sea 172 days, and covered 16,163 nautical miles.

R/V *Ellen B. Scripps* was utilized extensively for short cruises during the year; in all, on some 40 trips, most of which were for five days or less. In logging 9,298 nautical miles during her 165 days at sea, the *Ellen B.* saw a variety of oceanographic work. Included was the testing of microstructure instrumentation, biological oceanography, work with deep-sea capsules, and net tows, box coring, heat-flow studies, free-vehicle and deep-sea camera work, and operations with R/P FLIP.

Smallest of the working ships, R/V *ST-908* was used mostly for short day trips. At times, she ferried personnel to ORB and to other ships off San Diego, and she was also utilized in testing operational scale models of FLIP. Shortly after the end of the year — on July 13 — she was delivered to the University of California, Santa Cruz, at Moss Landing. On her final voyage, she made newspaper headlines by rescuing survivors of a pleasure craft that had overturned off Point Arguello.

Major Expeditions

Cato Expedition

Exploration of the oceans around the continent of South America has confirmed the existence of two geologic faults — one in the Gulf of Penas, off the coast of Chile, and the other in the Strait of Magellan, at the southern tip of South America.

This new information along with other data was gathered by scientists from four nations working aboard research vessel *Melville,* which docked at Nimitz Marine Facility on February 14, 1973, after completing the eight-month Cato Expedition.

Research during the cruise covered physical, geological, and biological oceanography investigations funded by the National Science Foundation and the Office of Naval Research. Participating nations included the United States, Argentina, Brazil, and Chile.

R/V *Melville* logged 36,820 miles during her work in the Atlantic and Pacific Oceans on Cato Expedition. The expedition's name was suggested by Joseph L. Reid, chief scientist on Leg VI of the cruise. He noted that Cato the Elder was a Roman statesman who advocated the exploration of the Atlantic. Thomas E. Chase, expedition coordinator, later applied the acronym *C*ycloidal *A*ctivities in *T*wo *O*ceans, a reference to the unique cycloidal propulsion system of *Melville.*

Noel L. Ferris was captain of the 2,074-ton, 245-foot-long *Melville* for the entire cruise, which left San Diego on June 7, 1972. It marked the last major expedition for Ferris, who first joined the Scripps fleet in 1951. He left in 1955, rejoined the Institution in 1961, and retired in mid-1973.

Resumé of Scientific Findings

There follows, leg-by-leg, a brief resumé of scientific findings from the expedition:

Leg I. Dr. John A. McGowan was chief scientist for work in the Pacific en route to Honolulu from San Diego. A prime objective was to study biological problems in order to better understand the community structure of marine life and its function. Several segments of the community were studied: 1) interaction between predators and prey; 2) productivity of the area; 3) input of nutrients; 4) light energy; and, 5) pollutants.

Dr. McGowan pointed out that no stable community structure exists in the California Current. A representative sample was taken in the North Pacific Central Gyre, and the data showed that a stable community structure is present in that gyre. This study was continued on Leg II in the South Pacific Central Gyre, where stable community

R/V *Oconostota*

R/V *Alpha Helix*

structure was found. Each gyre was millions of square miles in area. One objective of this study was to determine why community structures exist in some parts of the world's oceans and not in others.

Dr. McGowan's group also looked at nitrogen fixation in ocean plants. They learned that one particular plant, trichodesmeum, is able to use nitrogen (a fertilizer) by fixation, the biological process by which atmospheric gaseous nitrogen is made available for metabolism. Plants in the pea family use this process, which eliminates the need for a compact preparation of nitrogen for fertilization. Trichodesmeum was found in an area of the ocean previously thought to be relatively sterile.

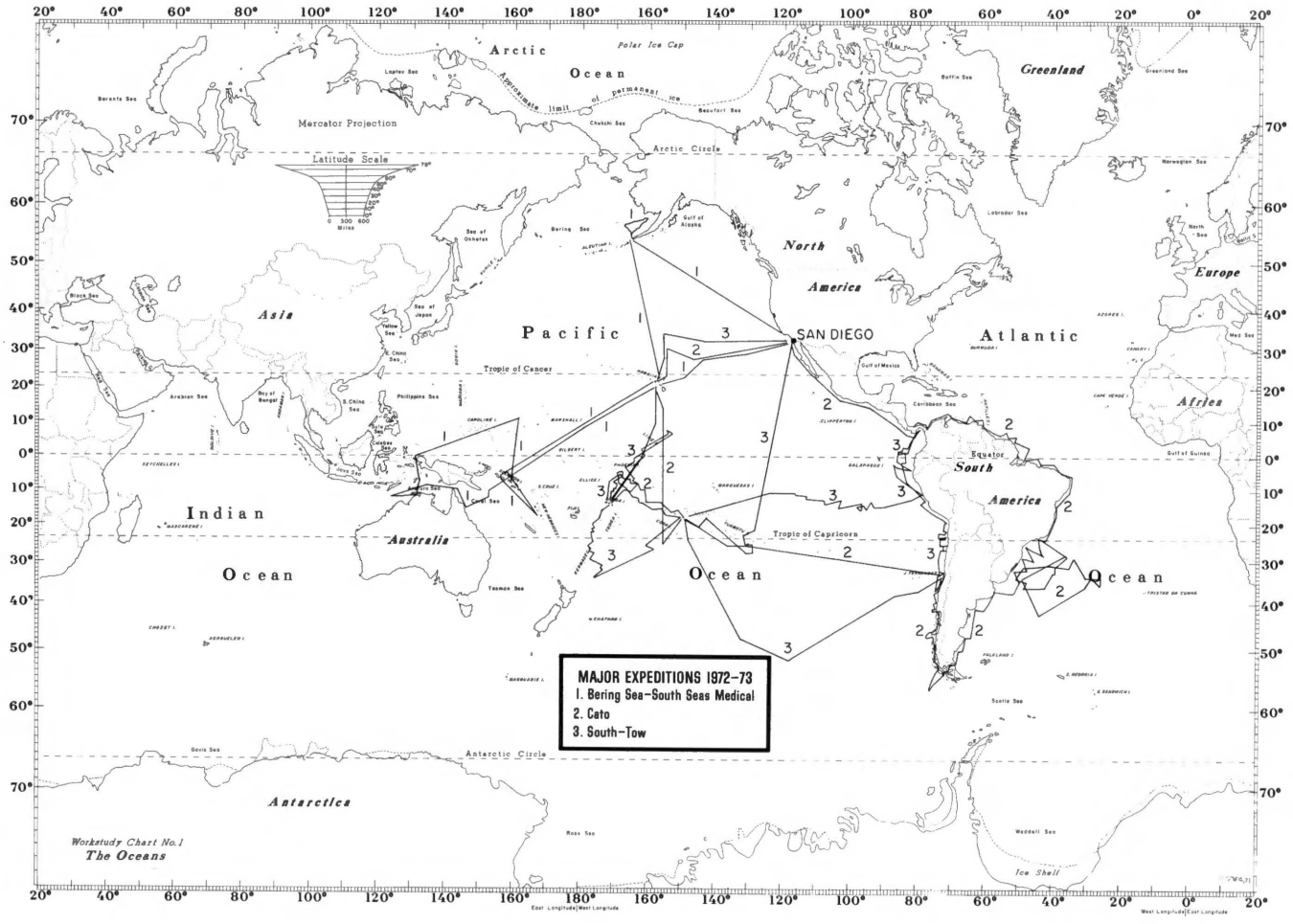
It was also discovered that the combination of a parasite inside the underwater plant diatom (yellow-green algae) likewise fixes nitrogen. Data showed that some plants in the ocean get a fraction of their phosphate (another fertilizer) requirement from the atmosphere. This fallout was noted when the phosphate content in the ocean was not enough to account for the phosphate intake of the plants.

Leg II. Under Dr. Michael C. Gregg, chief scientist from Honolulu to Papeete, Tahiti, vertical profiles of temperature and salinity were measured in the Equatorial Undercurrent and at another location 25 degrees South. Dr. Gregg said surprising features were found, adding, "We discovered microstructures that were not expected to be in the particular depth (457 m) of water that we measured." Microstructures are the smallest scale of variability for seawater temperature and salinity.

During this leg, biologists from the Marine Food Chain Group investigated the distribution of basic plankton in the ocean.

Leg III. Peter F. Lonsdale, a graduate student and chief scientist, conducted an ocean-bottom geological survey 966 km north of Samoa to collect core samples and measure currents.

The information obtained was the basis of Lonsdale's doctoral thesis on the interaction between bottom currents and sediment. His group studied the effects of strong bottom currents on sediments, and examined the erosion and the redeposition of sediment. These exper-



iments were conducted in the Samoan area because currents there are known to be particularly fast on the bottom — one-half knot at six kilometers.

Another graduate student measured the flux of helium, which may be coming out of the center of the earth, through the sediments collected. Measurements of helium were taken at specific points to see where and how fast the helium is going.

Leg IV. From Papeete to Valparaiso, Chile, Dr. Charles S. Cox, chief scientist, directed the measurement of structures of seawater temperature and salinity on a microscale in order to identify the mixing processes and the intensity of the mixing. This research was similar to the work done on Leg II by Dr. Gregg's group.

Dr. Cox continued his efforts on Leg V in the Drake Passage, off the tip of South America, with the ultimate aim of finding evidence of breaking internal waves and mixing brought about by the different speeds of diffusion of heat and salt in seawater. Forty successful observations were made.

Leg V. Chase was chief scientist for this combination biological and geological leg from Valparaiso to Rio de Janiero, Brazil.

In addition to recording a fault in the Gulf of Penas and one in the Strait of Magellan, the scientists took seismic reflection measurements within shallow water two-thirds of the way around South America. The data, which included underwater measurements and a record of the thickness of sediments, will aid in preparing topographical maps of the Pacific and South Atlantic Oceans and the Caribbean Sea. Magnetic measurements that were taken will aid geological investigations of the continental shelf by furthering the knowledge of the shelf.

On Legs V and VII, copepods (tiny, shrimp-like marine organisms) were collected from 69 shallow-water stations.

Three geologists and three physical oceanographers from the University of Chile boarded *Melville* in Valparaiso, and at Punta Arenas, Chile, a woman scientist from the University of Argentina joined the cruise to collect foraminifera. Foraminifera are benthic and planktonic protozoa possessing variously formed shells of calcium carbonate, silica, or chitin, or an agglomerate of materials.

Leg VI. The objective of Leg VI, with Reid as chief scientist, was to study the deep- and bottom-water movements in the southwest Atlantic Ocean and their contribution to the circulation of the deep waters of the world's oceans. The *Melville* departed on Leg VI south from Rio de Janeiro, and returned to Rio 40 days later.

Brazilian oceanographers from the Instituto Oceanografico da Universidade de São Paulo accompanied Scripps scientists aboard *Melville* for this portion of the expedition.

During this leg, 11 deep-current measurements were made and 51 measurements of temperature, salinity, oxygen, and nutrient concentrations were taken under conditions that ranged from calm seas to rough, 50-knot-wind weather. Preliminary results of these data indicate that bottom water, moving northward from the Antarctic, and the southward-flowing water above it, from the North Atlantic, travel with quite high velocities (10 to 15 cm per second). Although the currents at great depths are variable, the mean velocities during 30-day periods were as high as five to ten centimeters per second.

Other data showed that part of the deep water moves in a large, counter-clockwise gyre and that the significant northward flow of Antarctic bottom water is made only through a deep western channel in the Rio Grande Rise, which lies at 30 degrees South latitude.

Leg VII. Chase was also chief scientist for Leg VII, from Rio de Janiero to Balboa, Canal Zone, during which biologists collected copepods with net tows.

Geological and biological data gathered included shallow-water seismic recordings of bathymetric and magnetic readings. A series of structural intrusions through the sediment in the Caribbean Sea was found.

Two scientists aboard from the Smithsonian Institution studied parasites living on large, spiny, sea urchins.

Dr. Pat Wilde, University of California, Berkeley, participated in Leg VII to collect water samples just off the Amazon and Orinoco Rivers to measure ion content. He also measured movement of sand waves at the mouths of the rivers.

Leg VIII. The last leg, with Dr. Russ E. Davis as chief scientist, left January 15, 1973, from Balboa, en route to San Diego, principal work involved measuring the growth rate of ocean waves in the Gulf of Tehuantepec, off the coast of Mexico.

South-Tow Expedition

When R/V *Thomas Washington* tied up February 21, 1973, at Nimitz Marine Facility, she ended a 12½-month, 47,486-mile, five-nation Pacific Ocean cruise that included a wide variety of biological, geological, and geophysical investigations.

Scientists from the United States, Chile, Peru, Ecuador, and France took part in the 13-leg South-Tow Expedition, which started from San Diego January 5, 1972, and was funded largely by the National Science Foundation.

Cruise coordinator was Dr. John D. Mudie, who was also chief scientist for two legs. James L. Faughn, John W. Bonham, and Alan W. Phinney shared duties as captain of the 1,302-ton, 209-foot *Thomas Washington.*

Besides Dr. Mudie, other chief scientists were Dr. Robert R. Hessler, Robert L. Wisner, Drs. Fred N. Spiess, Roger N. Anderson, James W. Hawkins, Edward L. Winterer, Michael M. Mullin, and John G. Sclater, then of Scripps, now of Massachusetts Institute of Technology.

Scientific findings included the recording of some 800 "events," or mini-earthquakes, within a 42-hour period over the Galápagos spreading center east of the Galápagos Islands;

Further evidence of seismic activity in that center by the sighting of a fish "kill" involving upwards of 80 dead and dying fish floating on the sea surface;

Distinct lack of fish near the bottom of the 8,063-m deep Peru-Chile Trench;

Continuing evidence of sea-floor spreading involving the Lau Basin and the ocean-bottom Pacific (crustal) Plate that is moving northwestward into the Tonga Trench;

A wide variation in the amount of heat flowing from the sea floor in the Galápagos spreading center;

Studies of a submerged plateau nearly the size of Texas, northeast of Samoa, and of sand dunes on the ocean floor;

Discovery of the first suite of hydrous rocks recovered from the eastern Pacific;

Studies of biological productivity concentrated in one location, and continuing investigations of the biological aspects of the North Pacific Gyre.

R/V *Thomas Washington*

R/V *Ellen B. Scripps*

For the delineation of fine-scale structures during the geological and geophysical investigations, and especially at ridge crests, the scientists used the Deep-Tow instrument package developed by the Marine Physical Laboratory, for towing at great depths by the ship. The expedition's name was derived from the Deep-Tow nomenclature.

Dr. Mudie and his colleagues used a series of single sonobuoy (listening devices) "drops" on the Galápagos spreading center to record in one 42-hour period 800 "events," or mini-earthquakes, occurring 2,743 m below on the sea floor. They were tentatively identified as arising from an earthquake swarm in the immediate vicinity of the spreading center, some 322 km east of the Galápagos Islands. The scientists also detected indications of faulting and of earthquake activity along the crest of the center.

The mini-earthquakes were reminiscent of similar natural seismic activity of the Gulf of California. Early in 1972, Dr. James Brune, of the La Jolla Laboratories of the University's Institute of Geophysics and Planetary Physics, and his colleagues recorded some 1,000 "quakes" within a six-hour period. Dr. Mudie concluded that even though fast-spreading, mid-ocean ridges, such as the Galápagos spreading center, are not sites of frequent major events, they are the location of frequent microactivity.

During these joint Scripps-Woods Hole Oceanographic Institution studies, more than 80 fish that appeared to have been killed or stunned by a sea-floor pressure wave, were observed floating on the sea surface. The fish - three of which were returned to Scripps for study - were seen within 804.1 m of a location directly above the crest itself.

Swim Bladders Ruptured

Scripps scientists determined in studying the specimens that the specimens' swim bladders had been ruptured. Generally, bottom fish have grossly distended swim bladders caused by gradual decompression of the fish as they are raised through the water column. The fish under study, however, had ruptured swim bladders and no displacement of internal organs, a fact suggesting the fish were killed or stunned by a pressure wave at bottom caused by an earthquake or by volcanic action.

While his party was in the Galápagos spreading center, Dr. Mudie noted a developing El Niño condition. The scientists took expendable bathythermographs and wind and current observations that showed a general warming of the surface water and extending to a depth of some 450 m. The water was warmer than normal by about 3°C.

Heretofore, most of the knowledge about the El Niño phenomenon has been acquired from shore stations and weather observations made by passing ships. This phenomenon has been associated with meteorological changes in the eastern equatorial Pacific and its adjoining land masses, and it has a profound impact on the natural and artificial fish predators.

Under normal conditions, the Southeast trade winds cause upwelling off the coast of South America. An El Niño condition is presumed to be caused by a long-term diminution of wind stress that reduces the amount of upwelling. Thus, the reduction in supply of cool, deep waters to the surface allows the surface waters to heat up.

Peru-Chile Trench Operations

In the Peru-Chile Trench operations, Wisner reported that photographs taken by Scripps-developed, baited, still and movie cameras revealed a distinct lack of life at and near the bottom of the Trench, at 7,010 m and deeper.

He said no fishes, starfishes, brittle stars, or sea cucumbers were observed at those depths, adding that this paucity of life is not readily explained. The deepest that fishes were taken by Wisner and his party, using a set line, was at 4,583 m, from a bench on the eastern slope of the Trench, off Taltal, Chile. Films showed a few other fishes present that were not taken by hook or trap. No fishes were seen at 4,610 m on the abyssal plain west of the Trench.

Wisner said it seems reasonable to conclude that bottom fishes are not numerous in deeper areas of the Trench, or that capture techniques are not adequate, although identical techniques have been "tremendously" successful when used in the northeastern Pacific.

New Oceanic Crust

In the Lau Basin-Tonga Trench-Louisville Ridge studies, Dr. Hawkins and his colleagues learned that the magnetic anomaly pattern in the 322-km-wide Lau Basin, lying 1,609 m below the sea between Fiji and Tonga, indicates opening in an east-west direction at about two centimeters a year. Rocks dredged from a ridge crest in the Basin "are remarkable fresh oceanic-type basalt," and are forming a new oceanic crust in a manner similar to that which may have formed the Atlantic Ocean. Cruise data provide strong support for the hypothesis that the Lau Basin is thus being enlarged by crustal dilation.

This is unusual, Dr. Hawkins says, because, on the other hand, the Tonga Trench area is a zone of crustal compression; that is, the Pacific Plate and the Louisville Ridge (the latter long and narrow and some 4,572 m high) that cuts across the southern Pacific to a point at the Tonga Trench, are both moving northwest at about nine centimeters a year.

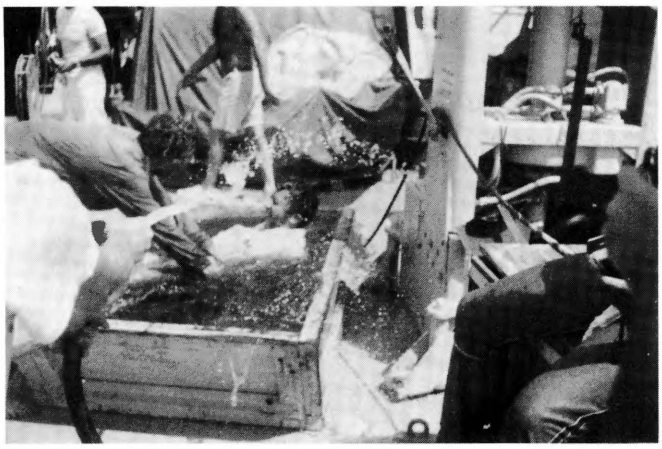
Thus, the Lau Basin and the Louisville Ridge are converging at a rate of about 11 centimeters a year. Cruise data show that, whereas the Louisville Ridge had been considered to be a fracture zone trace, surveys indicate now that it may instead be a line of volcanoes being formed either on a crack or over a hot part of the mantle as the Pacific Plate moves northwest into the Tonga Trench. At least eight or ten of these volcanoes were studied in detail for the first time, and rocks were dredged from them. The scientists mapped about 644 km of the Louisville Ridge, and the surveys increased man's knowledge of it by 25 percent, Dr. Hawkins estimates.

Manihiki Plateau Sediments

An accumulation of sediments 100 million years old and several thousand meters thick was noted on portions of the Manihiki Plateau, a submerged area about the size of Texas some 483 km northeast of Samoa. The Plateau rises three km above the sea floor to within three km of the sea surface. By dredging and coring, Dr. Winterer and his colleagues were able to trace many older sedimentary layers over most of the Plateau's surface.

R/V *ST-908*

R/V *Alexander Agassiz*



Crossing the Equator for the first time appears to be all fun and games, as indicated by this photograph taken aboard R/V Thomas Washington *during South-Tow Expedition's Leg 12.*
South-Tow Expedition

Dr. Winterer said a large amount of erosion on the Plateau has occurred during the last few million years, with some 914 m of sediments having been dissolved and eroded by ocean currents down to hard rock. Surveys suggest that the deep currents from the Antarctic once flowed north through the middle of the Plateau and also east of it, but measurements by Scripp's Joseph L. Reid indicate the deep currents are now flowing only around the Plateau's western end.

A detailed survey was accomplished by Dr. Winterer's group at the southern end of the northwest-southeast trending Line Islands chain (Christmas, Fanning, Washington, and Palmyra Islands and the Kingman Reef, some 1,207 km south of Hawaii), near the Equator, in anticipation of drilling by the Deep Sea Drilling Project. That DSDP operation was designed to test the hypothesis that the Line Islands were formed by motion of the Pacific Plate over a hot spot some 80 km below the earth's surface.

Galápagos Center Studied

Working in an area of some 8,047-square km north of the Galapagos Islands, in the Galápagos spreading center, Dr. Sclater and his party recorded the amount of heat flowing from 130 locations on the sea floor, 2,743 m beneath the sea surface. The area is in a deep, active crest where the ocean floor is being formed as an intrusion zone that starts at the East Pacific Rise, near the Equator, and ends in a larger fracture zone, called the Panama Fracture Zone, just south of Panama.

Dr. Sclater considered as significant 1) the large number of stations worked; 2) the fact that of the 130 stations worked, the precise positions of some 40 were located to within .049 km on the sea floor, thanks to transponder beacons left on the sea floor by scientists from the leg just previous to Dr. Sclater's; and 3) the fact that the heat flow on the Galápagos spreading center is "very variable from 20 heat flow units to one, within a distance of five to six km."

The high variability of heat-flow temperatures recorded is believed to be caused by hydrothermal circulation of ocean water among the rocks, causing a condition resembling the hot springs and geysers of Yellowstone Park or those found in Iceland.

The Galápagos spreading center runs in an east-west direction, flanked on one side by the Cocos Plate that runs north and on the other by the Nasca Plate that runs south. The relatively high heat-flow activity exists in the area because of the formation of new rocks as the Cocos Plate moves away from the Nasca Plate.

Line Islands Investigations

En route from Pago Pago to Honolulu, Dr. Spiess and his colleagues observed in their Line Islands studies that sediments had been clearly "chewed" away in the last half million years by currents flowing around rocky knobs, or hills, some nine to 12 m high.

In that area and also in two earlier cruises on which Dr. Spiess was chief scientist (from Callao, Peru, to Guayaquil, Ecuador, and in the region around Pago Pago), numerous sea-floor sand and mud dunes were photographed.

Between the Galápagos Islands and Ecuador, the scientists observed these sand waves, or dunes, on one side of the bottom of a valley to the north of the Carnegie Ridge, where they worked in a 32-square-km area at depths of 2,743 m. The group expected to see the dune phenomenon atop Carnegie Ridge, but currents had swept away the sediments. The dunes resembled those seen in the Arizona desert, and were one m high and 30 m wide and topped by three cm ripples.

Hydrous Rocks Discovered

On the way from Callao, Peru, to Papeete, Tahiti, Dr. Anderson's party discovered, 644 km south of the Galápagos Islands, what he described as the first suite of hydrous rocks every recovered in the eastern Pacific. These hydrothermally altered rocks were dredged from the Galápagos Rise, a "fossil," or dead ridge crest and spreading center east of the now active East Pacific Rise. The rock suite is very similar to "ophiolite suites" found on numerous continental margins today, such as the Francisan, of California, and the Apennines, in Italy.

The Anderson party's surveys also revealed that this "fossil" ridge is much more like the Mid-Atlantic Ridge than the East Pacific Rise. This suggests a "radical" change in the sea-floor-spreading rate that accompanied the "jump" in the spreading center from the Galápagos Rise to the now active East Pacific Rise, 805 km to the west.

Complete Sea Bottom Community

Dr. Hessler reported what he considered to be one of the most complete sampling of deep-sea bottom communities in a single ocean location. He and his colleagues worked for four days in an eight-to-sixteen-km-square area 4,023 km off the coast of Ecuador, between the Galápagos Islands and Pitcairn Island, in equatorial waters some 3,658 m deep and far from any continental influences on marine life.

The studies were conducted in an area of strong productivity resulting from upwelling caused by the Equatorial current system, with much food generated from the surface.

Dr. Hessler said the mass of data accumulated on his leg of the cruise would require years to compile, and eventually would provide answers to such questions as to the density and eating habits of the animals, the kinds, size distribution, and age of the animals; and the geographical distribution of the various species discovered.

On South-Tow's last leg, from Honolulu to San Diego, Dr. Mullin and his group conducted biological studies of the North Pacific Gyre, continuing investigations of ocean communities made the past several years by Dr. John A. McGowan during Climax Expeditions.

Bering Sea-South Seas Medical

R/V *Alpha Helix* returned to Nimitz Marine Facility on June 16, 1973, following 17 months of biological and medical research studies that took her from the polar seas of Alaska to the Great Barrier Reef of Australia.

The *Alpha Helix,* a laboratory ship serving the total scientific community, is supported by the National Science Foundation and operated by Scripps Institution.

R/V *George Melville*

The vessel departed San Diego on February 28, 1972. During its more-than-30,000-mile cruise, eight research efforts were conducted by scientists from the United States, Canada, England, Denmark, Sweden, France, British Solomon Island Protectorate, New Hebrides, Hong Kong, Japan, New Guinea, and Australia.

Investigations were conducted in the following areas: 1) Temperature regulation and 2) diving in marine mammals in the Bering Sea, 3) anthropological and genetic relationships between two isolated human populations in the Solomon4) disease patterns of isolated human populations in the Solomon Islands and New Hebrides, 5) high incidence of the genetically linked diseases achromatopsia and nearsightedness in the inbred human population of Pingelap Island in the mid-Pacific, 6) venomous sea snakes in the oceans north and east of Australia, 7) marine organisms in the vicinity of Lizard Island in the north Coral Sea, off Australia, and 8) photorespiration in marine algae, other plants, and coral at the Great Barrier Reef of Australia.

Captains for the 512-ton, 133-foot *Alpha Helix* during the expedition were Alan W. Phinney, Garrett S. Coleman, and Robert B. Haines.

Marine Mammals Studied

Work in the Bering Sea, headed by Dr. Robert Elsner of Scripps and Dr. Keith Miller of the University of Alaska, concerned temperature regulation and diving in marine mammals. From such studies it was learned how animals having body temperatures similar to those of human beings are able to survive in icy waters and how newborn seal pups regulate their body temperature under conditions of sub-zero weather.

During a Solomon Islands program, a team of medical anthropologists under Albert Damon, M.D., of Harvard University, studied two isolated human populations. This work investigated the anthropological and genetic relationships among these Pacific peoples, their diseases, vital statistics, and ecological adaptation to the traditional and currently changing environments. Medical and dental care was also provided for them.

Carleton Gajdusek, M.D., from the National Institutes of Health and the discoverer of the "slow virus" in man, led a medical expedition studying isolated human populations in the Solomon Islands and New Hebrides. The laboratories and support facilities of the *Alpha Helix* enabled the scientists to study disease patterns, population genetics in relation to congential defects, and epidemic diseases on the natives of 45 islands. Medical services were also brought to these peoples.

Genetically Linked Diseases

At Pingelap Island in the mid-Pacific, Ronald Carr, M.D., of the New York Medical Center, and his co-workers found a high incidence of the genetically linked diseases achromatopsia (total color blindness and high sensitivity to light) and nearsightedness in the inbred human population.

While the worldwide incidence of achromatopsia is one in 300,000, expedition scientists found a ratio of one affected individual in each 100 people on Pingelap. As a result of this study, 56 persons with combined achromatopsia and nearsightedness were fitted with prescription sun glasses. Their resulting visual improvement thus is now enabling them to lead productive lives in the community, something heretofore denied them.

Dr. William Dunson, of Pennsylvania State University, served as chief scientist of a team of research workers who carried out multidisciplinary studies of venomous sea snakes in the oceans north and east of Australia. The amount of information they obtained has added significantly to man's limited knowledge of the abundance, distribution, taxonomy, toxicology, physiology, and ecological relationships of sea snakes.

A group of neurobiologists headed by Professor S. Hagiwara of UCLA studied marine organisms in the vicinity of Lizard Island, in the North Coral Sea, Australia. They worked on a variety of fishes and invertebrates, available only in these Australian waters, a fact that provided especially favorable experimental materials. The overall aim of this part of the expedition was to learn more about several basic mechanisms of nervous functions. One group undertook a detailed analysis of the mechanisms of ionic permeability in muscle membranes in different fishes, concentrating particularly on one group of stingrays that show an unusually high permeability to anions (negatively charged particles). Another group studied the action of puffer fish toxin, known to block nerve excitation, and examined the resistance of puffer fish to their own poison.

Photorespiration Studies

Scientists also conducted investigations of photorespiration in marine algae, other plants, and coral at the Great Barrier Reef of Australia, this work having been under the direction of Dr. Edward Tolbert, of Michigan State University. In the past decade, plant scientists have biochemically characterized photorespiration in land plants, and have learned that it functionally reduces net photosynthesis and net plant growth. Certain tropical grasses, corn, and sugar cane, which circumvent this carbon dioxide loss, have the highest rates of photosynthesis and growth. The scientists on this leg of the expedition found that all forms of marine plant life had photorespiration. The process in the ocean plants differed in one important aspect from that found in land plants. The products of photorespiration in land plants are oxidized to carbon dioxide, while in the ocean only part is oxidized and the rest is excreted, this material being utilized by the zooplankton. Thus, photorespiration is a link in the food chain of the ocean. Another link revealed during this study was the excretion by the corals of mucous and wax which are consumed by the fishes.

THE GRADUATE DEPARTMENT

Graduate education is administered through the Department of the Scripps Institution of Oceanography. Within this Department curricular programs are offered in applied ocean sciences, biological oceanography, geophysics, marine biology, marine chemistry, geological sciences, and physical oceanography. Each curricular group has its own special requirements for admission (in addition to those applying to the Department as a whole) and its own course requirements and policies.

In the rapid evolution of modern oceanography, growth is often most vigorous at the boundaries of established disciplines, so that the interests of a given student may fall somewhere between the limits of two curricular programs. It is the intent of Scripps's graduate program to provide the maximum flexibility in meeting the specific interests of individual students.

The Department was chaired by Dr. Edward L. Winterer, professor of geology, who has been succeeded by Dr. Joseph R. Curray, professor of marine geology. Dr. Richard Rosenblatt, professor of marine biology, was vice-chairman. He has been succeeded by Dr. Michael M. Mullin, associate professor of oceanography.

GRADUATE CURRICULAR PROGRAM. A brief description of the seven curricular programs, whose 55 faculty members also serve in various research divisions, laboratories, and research groups, follows:

Applied Ocean Sciences (Dr. Victor C. Anderson). This curriculum is concerned with man's purposeful and useful intervention into the sea. Interdepartmental in nature, it combines the resources of the Graduate Department of Scripps and two engineering departments on the San Diego campus of the University; namely, Aerospace and Mechanical Engineering Sciences and Applied Physics and Information Science. An attempt is made to produce modern engineers with a substantial training in oceanography and oceanographers with a significant ability in modern engineering. Instruction and research are not restricted to structural, mechanical, material, electrical, and physiological problems operating within the ocean, for they include the applied environmental science of the sea as well. Since physical, chemical, geological, and biological aspects of the oceans and all forms of engineering may be involved, the curriculum provides maximum flexibility in meeting the needs of each individual student.

With Scripps Pier as backdrop, John E. Penery, right, of Lemon Grove, Calif., president of the Inter-American Education Foundation, and his guest, Dr. Hector Mayagoritia D., left, of Mexico City, Sub-Secretary for Higher Education of Mexico, confer with Director Nierenberg.

Biological Oceanography (Dr. James T. Enright). Biological oceanographers are concerned with the interactions of populations of marine organisms with one another and with their physical-chemical environment. Research activities in this curriculum include studies of the factors influencing primary and secondary productivity and nutrient regeneration, food-chain dynamics, community ecology of benthic and pelagic forms, population dynamics, and fisheries biology; taxonomy and zoogeography of oceanic organisms; and behavior as it affects distribution and sampling problems. The curriculum is designed to prepare students for original research and teaching in this interdisciplinary field.

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

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

Marine Chemistry (Dr. Charles D. Keeling). 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 basis for research programs. These include investigations of the carbon system, natural products, chemical interactions between marine organisms, physical and inorganic chemistry of sediment water systems, organic chemistry in the marine environment, distribution of noble gases in seawater, and effects of pollutants on the marine environment.

Geological Sciences (Dr. James W. Hawkins). This curriculum emphasizes the application of observational, experimental, and theoretical methods of the basic sciences to the understanding of the solid earth, ocean, atmosphere, and the solar system. Principal subprograms at Scripps are marine geology, petrology, and geochemistry. Expedition work at sea and field work on land are emphasized as an essential complement to laboratory and theoretical studies. Marine geology is the field of study concerned with the origin, properties, and history of ocean basins and with the geological processes that affect them. Petrology is the study of the origin and history of the rock complexes of the earth's crust and upper mantle, with emphasis on the igneous, metamorphic, and sedimentary rocks of the oceanic island, abyssal plains, and deep-sea trenches; the study of characteristics and interrelations of the oceanic and continental crust; and studies of lunar and meteoritic materials. The geochemistry program is designed for students with undergraduate majors in either geology or chemistry. Areas of advanced study and research include the geochemistry of the ocean, the atmosphere, and the solid earth; nuclear geochemistry; studies of volcanic and geothermal phenomena; the interaction of sediments with seawater and interstitial waters; geochemical cycles; and the history and composition of the ocean and sedimentary rocks.

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

GRADUATE STUDENTS AND DEGREE RECIPIENTS. In the fall of 1972, 41 new students began their graduate studies. Of these, 7 were in marine biology, 5 in geophysics, 9 in biological oceanography, 6 in physical oceanography, 5 in marine chemistry, 5 in applied ocean sciences, and 4 in geological sciences. Nineteen were California residents, 18 were from out-of-state, and 4 were from foreign countries. Enrollment at the start of the 1972 school year totaled 162 students.

During the Academic Year 1972-73, six Master of Science degrees and 22 Doctor of Philosophy degrees were awarded by UCSD to students having completed advanced studies at Scripps. The names of degree recipients and the titles of doctoral dissertations are listed in Appendix E.

Prior to lecture to staff and students, submersible expert Jacques Piccard, with briefcase, talks with, from left, Assoc. Dir. George G. Shor, Director Nierenberg, and Ron Linsky, head, University of Southern California Sea Grant Program.

RESEARCH ACTIVITIES

Advanced Ocean Engineering Laboratory

Established in late 1968, with funding from the Advanced Research Projects Agency (ARPA) and contracting through the Office of Naval Research, the Advanced Ocean Engineering Laboratory (AOEL) commenced advanced engineering investigations in diversified, but often related, oceanographic fields. AOEL's program administration and support traverses several departments within Scripps. There are presently eight separate areas of research at AOEL; four are associated with the field of advanced marine technology and the balance with that of marine physics.

Stable Floating Platform — Dr. Fred N. Spiess

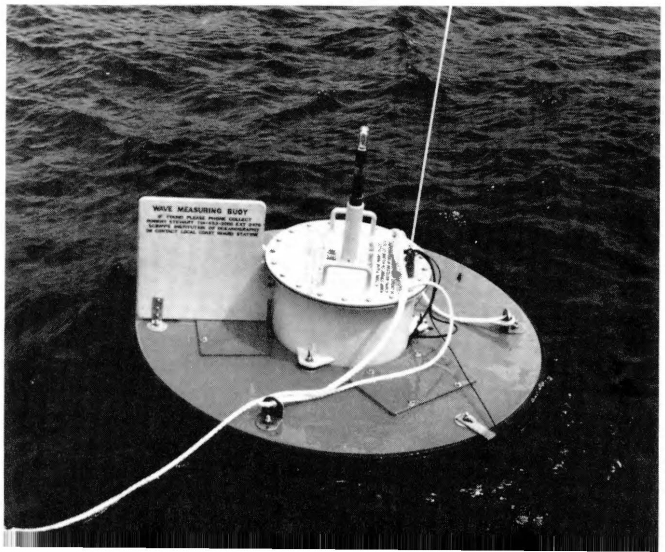
The goal of the Stable Floating Platform (SFP) program is to conceive, design, build, and demonstrate the feasibility of large SFPs in open seas. Since the 1972 *SIO Annual Report,* notable progress has been achieved with the earlier-developed catamaran model and the later-configured, barge-like model. Two eighth-scale, catamaran model modules were successfully coupled at sea (off the Coronado strand) with instrumentation to compare forces measured on the modules with sea-state spectra. As a follow-on to the catamaran efforts, an eighth-scale, barge-like model was constructed, outfitted, and initially "flipped" in San Diego Harbor. It is planned to couple the barge-like model with two satellite legs forming a triangular base from which, in full scale, an ocean SFP could be established. Some of the possible SFP applications include airfields and nuclear power plants located away from areas of population, ships ports, drilling stations, and fish processing plants, just to name a few.

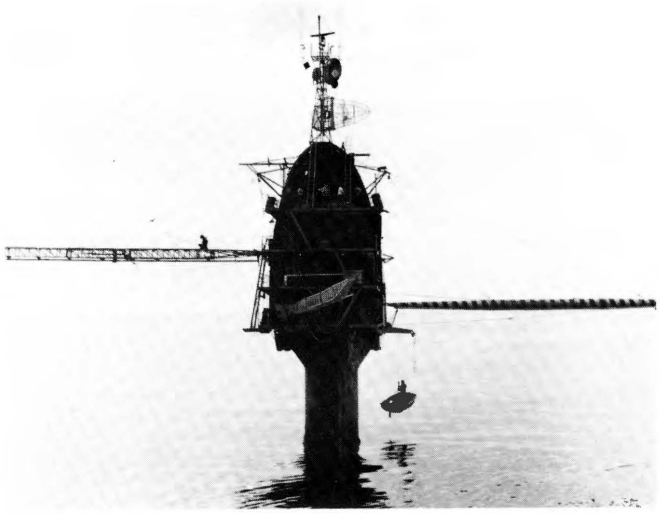
Nearshore Engineering — Dr. Douglas L. Inman

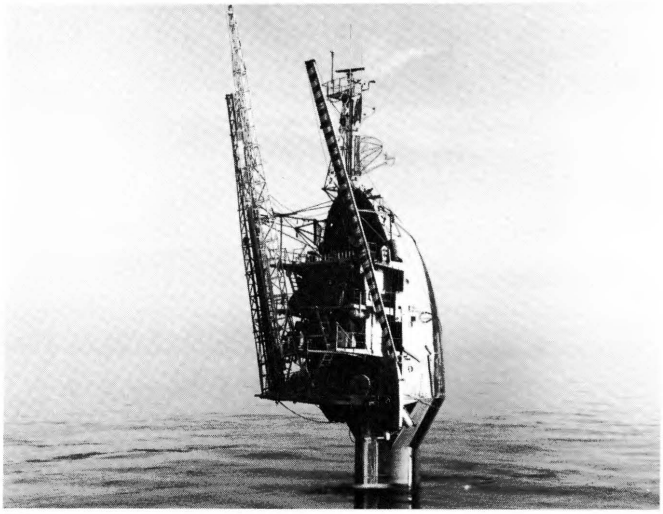
Harbors and seaside communities have long been plagued by sand movement that causes the loss or build up of sand. This research effort, investigating oscillatory flow over asymmetrical and symmetrical ripples, is attempting to control the direction of sand movement in the nearshore zone. Encouraging sand-control results have been achieved by utilizing a scaled-down, ripple-shaped, concrete array (1X2 m), called phase-dependent roughness elements, in limited ocean tests. A full-scale fiberglass array (2X3 m), was subsequently ocean tested, which resulted in the fiberglass devices being swept away because of a severe storm. Therefore, future arrays will need to be made of concrete and deployed with mechanical assistance.

Surface-following wave buoy developed by Dr. Robert H. Stewart, of Advanced Ocean Engineering Laboratory, is shown in operation off Monterey, California. The five-foot-diameter buoy is used to measure ocean-wave directional spectra, for comparison with radio-scatter data.

Dr. Robert H. Stewart







With her booms deployed in one photo and contracted in the other, FLIP is seen on station near San Clemente Island during a check-out cruise for Advanced Ocean Engineering Laboratory's Internal/Surface Wave Interaction and Microstructure Measurement Program.

Dr. Carl Friehe

Electromagnetic Roughness of the Ocean Surface — Drs. Robert H. Stewart and Joseph W. Joy

More commonly referred to as radar backscattering, this promising research and development effort utilizes radio signals scattered from the sea surface to determine the directional spectrum of ocean waves. This project is being conducted in conjunction with Stanford University. A second Hawaiian experiment (the first occurred several years ago) was carried out in September to measure directional spectra of a fully developed homogeneous sea. The seaway was measured directly using an accelerometer-type wave buoy. In November, the scientific party moved out to Wake Island to make observations of electromagnetic sea scatter. Wind and sea conditions were varied at Wake Island and the observations included the recording of the growth and decay of a distant tropical storm that reached typhoon strength. Off Southern California, San Clemente Island was also the site of several experiments in early 1973. For the first time, ocean surface currents were measured by radar and correlated with measurements made by conventional means. A "quick-look" examination of data from the above experiments showed them to be of good quality. Data analyses will be completed during 1973-74.

Wave Breaking in Deep Water — Dr. William G. Van Dorn

This program is described under the Ocean Research Division section of this report.

Microstructure Measurement — James L. Cairns, Gordon O. Williams, Drs. Walter H. Munk, Frank E. Snodgrass, Charles S. Cox, and Michael C. Gregg

Portions of this research effort are mentioned under the Institute of Geophysics and Planetary Physics and Ocean Research Division sections of this report.

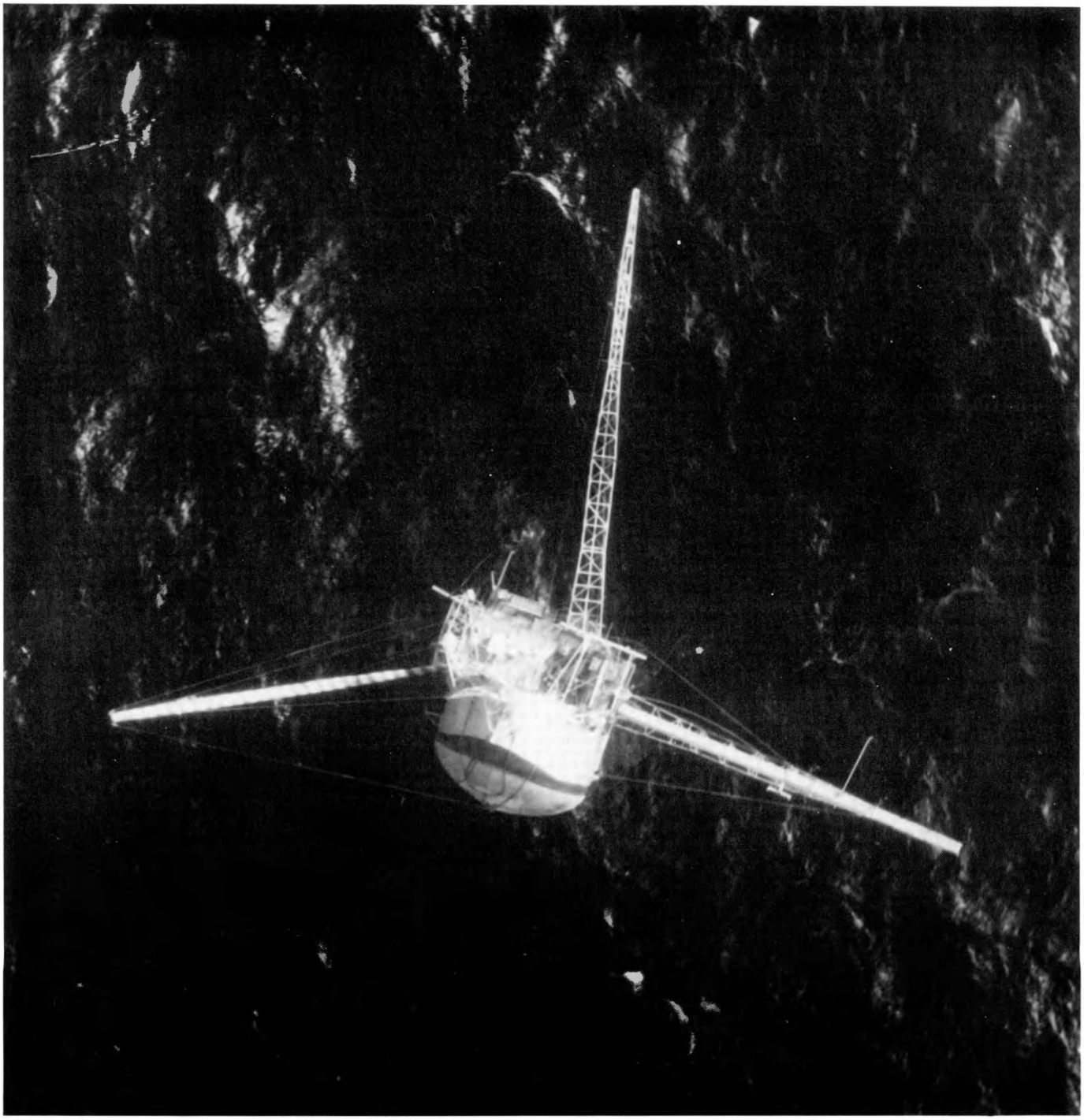
Internal Waves — James L. Cairns, Gordon O. Williams, and Drs. Walter H. Munk and Frank E. Snodgrass

This study is covered under the Institute of Geophysics and Planetary Physics section of this report.

Turbulence Measurements — Drs. Carl H. Gibson, Carl A. Friehe, and Francis H. Champagne

A description of this research effort is noted under the Ocean Research Division section of this report.

Atmospheric Boundary — Dr. Charles W. Van Atta and Joel T. Park



This is not a satellite, but a striking, overhead view of FLIP with her booms deployed. Photo was taken by U.S. reconnaissance plane in December, 1972, during an Advanced Ocean Engineering Laboratory (AOEL) sea experiment. Underway work was part of AOEL's Internal/Surface Wave Interaction and Microstructure Measurement Program.

U.S. Navy

The purpose of this research is to explore fine-scale measurements of wind temperature and velocity and their derivatives taken from the U.S. Naval Undersea Center (NUC) oceanographic tower off San Diego. A traversing boom with instrumented platform was built and installed on the tower. Various sensing devices for measuring wind velocity, direction, and temperature were mounted on this instrument platform. The wind recording instruments were calibrated in a university wind tunnel. Two experiments were completed during this period. In the first experiment, velocity and temperature were measured at a distance approximately 5 m above the water; and in the second, only velocity, at 19 m. Two major objectives were achieved during the period of this contract. First, a capability was established for the measurement of velocity and temperature in the atmospheric boundary layer. Second, the NUC tower proved to be a useful platform for measuring fine-scale structure of atmospheric turbulence over the ocean. The data that were acquired will be useful for future experiments.

Operational Support — Gerard H. Fisher

Besides providing general and administrative support, AOEL is responsible for supplying the marine physics programs with various services for at-sea support. Services included FLIP modifications, shuttle-boat charters, communications, providing time-lapse camera equipment for photographing ocean slicks, equipment and supplies logistics, program integration, subcontracting, and assistance to the overall project.

Deep Sea Drilling Project

During the year ending June 30, 1973, the D/V *Glomar Challenger* traveled more than 26,000 nautical miles, occupied and drilled 40 sites, and recovered nearly 6,000 meters of core. Statistics, however, tend to provide only a bare outline of the value of the work accomplished.

In the beginning of 1972, the *Challenger* entered the Indian Ocean for a year-long program of drilling and coring. Along with the discovery of coal and other shallow-water indicators on the Ninetyeast Ridge, one of the most outstanding features of the Indian Ocean drilling was the discovery of widespread hiatuses in sedimentary section. The thinned or missing section was found at at least 27 sites in both the eastern and western basins, and hiatuses were found centered on the Late Cretaceous, Early Tertiary, and Oligocene periods. Similar hiatuses have been recorded from drilling in the North Atlantic, Caribbean Sea, central Pacific, and Melanesia. The hiatuses might be related to changes in the patterns of oceanic circulation as the continents surrounding the Indian Ocean separated from Antarctica.

The oldest dated sediment in the Indian Ocean was recovered in the Argo abyssal plain off northwest Australia, where Berriasian (Early Cretaceous-basal Neocomian) or Tithonian (latest Jurassic) sediments were identified. Basal Neocomian sediments were also recovered just west of Perth and again west of the Exmouth Plateau. All these sites are located along the eastern edge of the Indian Ocean, adjacent to the Australian continental margin.

In the western Indian Ocean, the oldest sediment (Turonian-Coniacian; Late Cretaceous) was recovered near the African continental margin north and south of Madagascar. Extrapolation of the age gradient toward Africa indicates an Early Cretaceous age at the continental margins. Recovery of sediments of Late Cretaceous age from the continental rise off the coast of Tanzania north of Madagascar invalidates the suggestion that Madagascar was attached to the Tanzania coast during the Cretaceous.

Drilling on the Ninetyeast Ridge on Leg 26 supported the earlier discovery (by Leg 22 scientists) that the ridge is a volcanic structure that becomes progressively older to the north. This suggests that it was constructed from a localized volcanic center. The drilling results also showed that the ridge formed at depths near or at sea level and further south than its present latitude. The ridge is the same age as the plate to the west and therefore, at least in the northern portions, belongs to the Indian Plate.

The sediments of Broken Ridge tell a remarkable story of vertical tectonics. A thick, 1,000-meter section of Paleocene and Cretaceous limestones was deposited in a shallow, cold-water, marine environment, suggesting an origin in more southerly latitudes. In the Eocene the ridge was uplifted above sea level with erosion angularly truncating the limestone, and a thin layer of littoral sands and gravels deposited. Broken Ridge then subsided to its present depths. The scientists on Leg 26 believe the uplift was associated with the initiation of sea-floor spreading along the southeast branch of the Indian Ocean Ridge which split Broken Ridge from the Kerguelen Plateau.

Drilling on Naturaliste Plateau also contributed to the list of surprises from the Indian Ocean. Plateaus extending from continental blocks, such as the base of Naturaliste Plateau, are commonly associated with subsidence; for example, Orphan Knoll off Labrador, Rock Bank, and the Bahama Bank. In this case, the evidence points to a deep-sea environment in Middle Albian (Early Cretaceous) with uplift since that time to the Miocene. Naturaliste Plateau has subsided again since the Miocene. Cold-water fauna from the Cretaceuous sediments indicate a more southerly latitude during this period, with warming through time as sea-floor spreading carried the plateau northward. An Eocene-through-Early Cretaceous hiatus on the Plateau is attributed to erosion, possibly resulting from initiation of the Circumpolar Current.

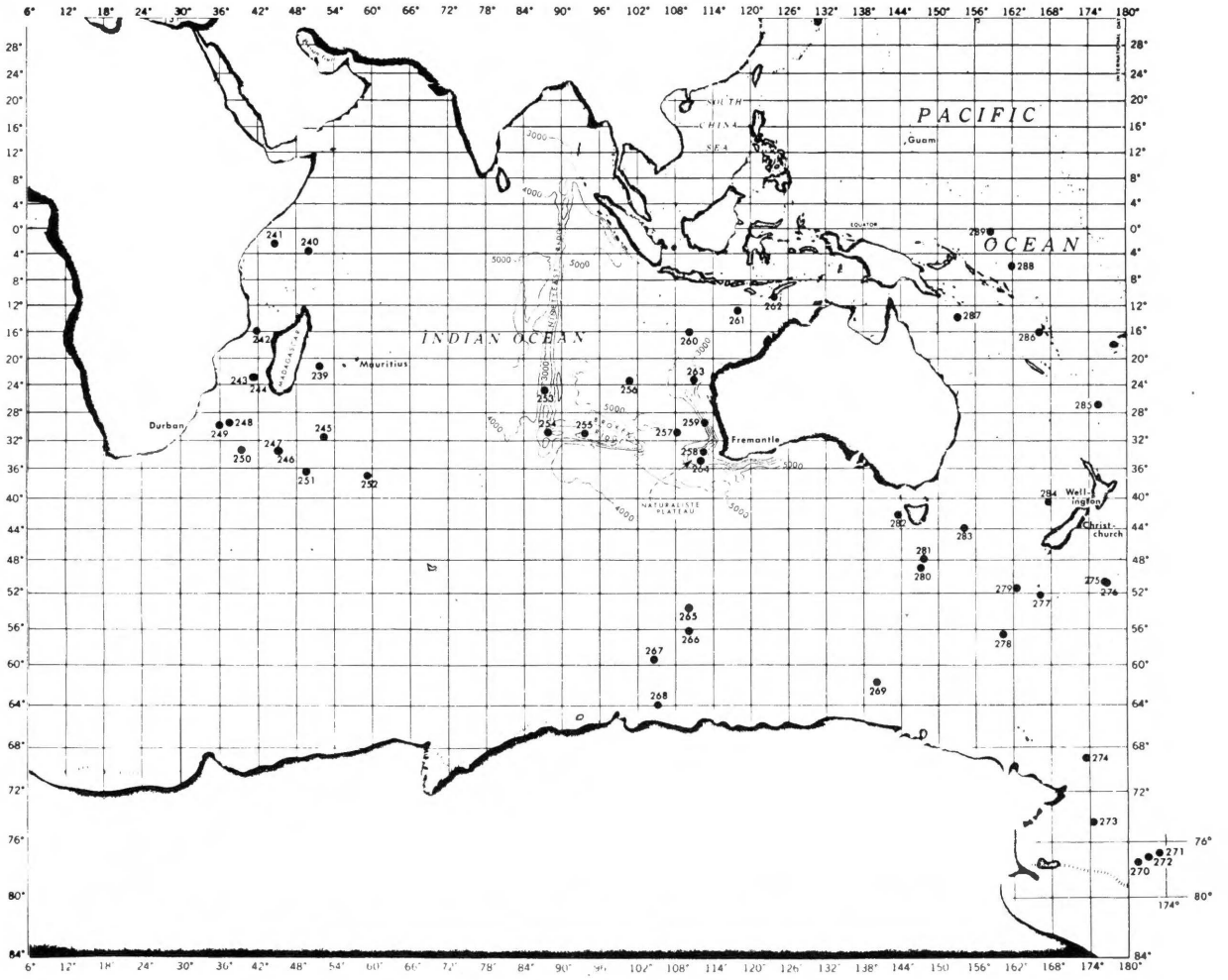
It appears that the oldest crust in the Indian Ocean is in the eastern basin and that most of the eastern Indian Ocean originated in more southerly latitudes and has been moved northward with the initiation of sea-floor spreading on the Pacific-Antarctic ridge in Eocene time.

A 70-day cruise in Antarctic waters during January and February, 1973, proved to be very successful. Without serious technical problems or loss of equipment, the *Glomar Challenger* returned safely to Christchurch, New Zealand, with 1,406 meters of sediment, almost a record recovery.

The scientists were able to demonstrate that extensive glaciers covered the Antarctic continent by Early Miocene (20 million years ago) and perhaps locally in the Late Oligocene. The ice advance climaxed about 4 to 5 million years ago, then abruptly retreated to about the present position. Subsequent fluctuations in the extent of glaciation are considered relatively minor.

Acoustic basement (basaltic) was sampled at four sites and in each case the age of the basal sediment agrees with that predicted from magnetic lineations.

Dr. Melvin N. A. Peterson, right, manager of Deep Sea Drilling Project, describes deep-sea sediment cores to scientists from Russia visiting on campus. From left: A. P. Metalnikov, executive secretary, USSR Oceanographic Committee; Academician A. G. Kolesnikov, director, Marine Hydrophysical Institute, USSR Academy of Sciences; and Academician L. M. Brekhovskikh, leader of seven-member Soviet Scientific Exchange delegation to the United States. He is also secretary of the Department of Oceanology, Physics of the Atmosphere, and Geography of Soviet Academy. Scripps Director Nierenberg led a similar team of American scientists to Russia two months prior to visit here by Russian delegation.



Map indicates sites of 1972-73 Deep Sea Drilling Project operations in Indian and Pacific Oceans and, for the first time, bordering Antarctica.

On the Ross Shelf thick, pebbly and silty clays were deposited under marine glacial conditions without major interruption since at least Early Miocene to earliest Pliocene. These dipping beds were planed off during Early Pliocene by the grounded ice shelf extending well north of its present position. Below these sediments a gray-foliated marble and calc-silicate gneiss was recovered from what has been called basement on seismic records. These metamorphic rocks are similar to the Koettlitz Marble found 400 km to the west in the Royal Society Range. If this correlation is correct, the age of these metamorphic rocks is Early Paleozoic.

Subsidence of the Ross Shelf, at least in the area of two sites, from sea level to about 640 m has occurred since the Late Oligocene.

The *Glomar Challenger* encountered adverse weather conditions on the second and final leg of the first Antarctic season of drilling. Nevertheless, the scientific and technical crew of Leg 29 was able to resolve most of the scientific questions they set out to answer. These questions hinged on three basic problems: 1) the history of plate motion in the region between Australia and Antarctica, 2) the evolution of the Antarctic Circumpolar Current, and 3) the climatic history of the southwestern Pacific Ocean.

The history of plate motion involves the fragmentation of various land masses in this region, the history of which had been only partially revealed by earlier DSDP drillings. It is now clear that fragmentation first involved New Zealand, which drifted away from Australia/Antarctica at some time between 60 and 80 million years ago. Shortly thereafter (55 million years ago), Australia separated from Antarctica and moved northward.

The recovery of possible Precambrian schist at one site confirms the continental origin of the South Tasman Rise. Basaltic basement obtained from the northern Macquarie Ridge is of Early Miocene age. This age (20 to 25 million years) places important constraints on reconstructions of the area south of New Zealand. A basement sample from the magnetic quiet zone taken at yet another site is apparently a normal, oceanic, pillow basalt. This eliminates the suggestion that the "quiet zone" represents foundered continental material and indicates that some as yet unknown later process has destroyed the original magnetic signature of the crust.

Of great significance is the unraveling of the complex Cenozoic history of the Antarctic Circumpolar Current. The complexity of its history was alluded to on several earlier DSDP legs. It now appears that although initial spreading between Australia and Antarctica commenced in the late Early Eocene, complete development of this current did not begin until the Middle Oligocene, when final rifting occurred south of the South Tasman Rise. Before late Oligocene time, Antarctic Bottom Water formed a deep, erosive, western, boundary current flowing northward through the Tasman and Coral Sea areas and causing the regional Oligocene unconformity noted on Leg 21 (November, 1971 - January, 1972). Since the circumpolar flow was

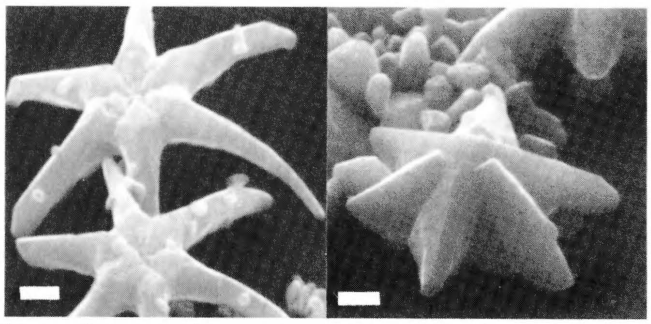
established in the Late Oligocene, a Neogene submarine unconformity was formed south of Australia and New Zealand, and sedimentation resumed in the Tasman and Coral Seas.

The story of Cenozoic climate in the Southern Ocean can be read from the record of glacial detritus and productivity of the surface plankton. The microfossils record significant warming during the Early Miocene and obvious cooling in the Late Miocene and earliest Pliocene. Detritus of probably ice-rafted origin occurs in restricted intervals encompassing Mid-Late Eocene, Mid-Late Oligocene, Early Miocene, Late Miocene, and Pliocene and Pleistocene times. The latter interval records the greatest concentration of ice-rafted debris. Confirmation of these results awaits further work with the scanning electron microscope.

In the areas of engineering and management, significant achievements were recorded during 1972-73. Specifications for the design and construction of a new building to include additional core repository space were developed and put out for bid (full utilization of the building was to be achieved in March, 1974). In regard to technical activity, 13 different programs were either completed or implemented. Among the more noteworthy were the Antarctic ship- and drill-system modifications, which proved to be operationally successful; a heave-compensation system was studied and ordered (this system is presently undergoing operational acceptance tests); a blow-out preventer/formation tester was studied and ordered; the re-entry system improved and updated; a drill string-sea floor locator was developed and ordered; and a progressive ship/system maintenance plan implemented. Foreign equipment analysis became an active DSDP study. Inquiries received as a result of this study were, and still are, being evaluated in light of their possible contribution to improving drilling and coring systems and operations.

In June, 1973, Soviet Premier Brezhnev visited President Nixon, during which time he and the President participated in the signing of a bi-lateral agreement on scientific study of the world's oceans. Inherent in that agreement was deep sea drilling and the understanding that the USSR would increase the tempo of its participation in DSDP. (Subsequently, the USSR became the first non-U.S. nation to formally participate in DSDP.) Additional meetings and negotiations on the same basis were undertaken with the Federal Republic of Germany, France, and other foreign governments.

Since the inception of the Deep Sea Drilling Project, scientific planning for cruises has been based upon advice from JOIDES (Joint Oceanographic Institutions for Deep Earth Sampling). JOIDES advisory panels, comprising scientists from various disciplines and each concerned with the drilling program for an entire ocean or sea, have demonstrated their effectiveness in provding guidance for an extremely successful reconnaissance drilling program that will have lasted for seven years by the end of Phase III of DSDP in June, 1975.



Figures show experiments on diagenetic changes in a Pliocene nannofossil ooze. Overgrowth occurred after subjecting sample to elevated temperatures (300° C) and pressure (3Kb). At left: discoaster from original sample. At right: same species after experiment. Bar scales equal 1μ.

Scanning electron microscope photos by P. H. Roth/C. G. Adelseck

Geological Research Division

Dr. Albert E. J. Engel and associates Sonja J. Itson, Allan Divis, Nancy Beddingfield, Dr. Celeste Engel, *et al.*, worked toward the publication of second and third phases of an extended examination of possible pre-Permian global and plate tectonics. One major phase of the study, based upon the petrochemical characteristics of orogenic belts ranging in age from more than 3.4 b.y. b.p. to the present, is scheduled to appear in the *Geological Society of America, Bulletin* (see illustration).

A comprehensive study of the initial ages and evolution of crustal segments in the Central Rockies is in preparation by Divis. Itson, Drs. Celeste Engel and Albert E. J. Engel are preparing a discussion of the secular changes in ratios of various crustal environments and the species of sediments and igneous rocks emplaced therein.

A summary paper by Drs. Celeste Engel and Albert E. J. Engel discussing earth-moon petrogenesis and histories has been submitted to *Icarus* for publication.

Dr. Wolfgang H. Berger and collaborators worked on carbonate distribution in the deep ocean. Together with Dr. Peter H. Roth, they extended studies on differential dissolution of calcareous microfossils to include coccoliths in addition to continuing their investigations on planktonic foraminifera. They found that coccoliths show characteristic preservation patterns on the sea floor that can be interpreted in terms of fertility, abyssal circulation, and chemistry at the sediment-water interface. The question of whether foraminifera and siliceous microfossils dissolve during settling or when on the sea floor was attacked during the Benthiface Expedition, June, 1973. Preliminary results indicate that virtually all such dissolution takes place on the sea floor.

The distribution of the present-day calcite compensation depth has been mapped, and attention was focused on geologically short undulations of the surface defined by all regional compensation depths. During glacials this surface apparently was generally lower than at present in the Pacific. Thus, the Pleistocene climatic variations produced interglacial dissolution pulses. The nature of these pulses is now being studied.

Long-term trends in carbonate deposition received continued attention and an attempt was made to define the plate stratigraphic framework within which such trends are to be viewed. In cooperation with Dr. Edward L. Winterer, the scientists made an effort to relate these aspects of carbonate deposition to acoustic stratigraphy. Earlier, experiments suggested that the original patterns of preservation of calcareous fossils determined the processes of diagenesis after burial, and the rate at which diagenesis alters the sediment (see illustration). These diagenetic changes in turn determine the acoustic "signature" of the buried sediment. The aim of these studies is to fashion reflection profiling into a useful tool of carbonate stratigraphy.

Dr. Yu-chia Chung continued his investigation on radium variation in the world's oceans. During the year, five vertical radium profiles were measured in replicates from seawater samples collected during the Scripps's South-Tow Expedition in 1972. These profiles are located on an east-west traverse across the East Pacific Rise from Peru to Tahiti. Although these profiles show only very small variation (less than 10 percent in deep water), a lower radium concentration is found in the deep water on both ends of the travers; *i.e.*, near the continent on the east and near Tahiti on the west. The increase from west to east is expected from the geochemistry of radium and large-scale circulation in the Pacific. The lower values observed near the continent may reflect the near-shore processes and continental effects. Dr. Chung also studied the variations of barium and silica in conjunction with radium in the Antarctic and Pacific Oceans.

A report on abyssal water temperature data accumulated during heat-flow measurements from the Pacific and Indian Oceans has been published as an SIO reference report. Dr. Chung also participated in the last leg of the Atlantic GEOSECS Expedition across the Atlantic from Dakar to New York in March, 1973.

Dr. Harmon Craig's group was primarily occupied with the Geochemical Ocean Sections Study's (GEOSECS) Atlantic Expedition during the year. Dr. Craig was chief scientist on R/V *Knorr* (Woods Hole Oceanographic Institution's ship) for Atlantic Leg 4 in the Equatorial Atlantic, and for Leg 7, the Antarctic leg from Ushuaia to Cape Horn, in January. He continued to serve on the three-man

executive committe of the GEOSECS National Advisory Council that directed the Atlantic program and planned Pacific GEOSECS Expeditions that are to begin in August, 1973.

In Africa during February, Dr. Craig, Valerie Craig, and Fred Dixon conducted a small-scale "oceanographic" expedition on Lake Tanganyika aboard the *Lady Alice II,* a U. N. -Food and Agriculture Organization (FAO) boat stationed at Bujumbura, Burundi. Other scientists in the party were Dr. John Edmond, of the Massachusetts Institue of Technology, and Drs. George Coulter and Wouter Ferro, of the Burundi FAO Laboratory. A hydrographic section was made from Bujumbura to the deepest section of the lake off Kigoma, Tanzania. Object of this program was the study of vertical mixing in a deep lake in which vertical advective transport may be insignificant.

Dr. Craig and Valerie Craig did field work in Greece during March, and worked in the National Museum of Athens and the British Museum, London, continuing their studies on determining the provenance of classical Greek marbles by stable isotope studies.

The research of Dr. Joseph R. Curray was again centered largely on work in the Bay of Bengal, the Andaman Sea, and the Sunda Arc of the northeastern Indian Ocean, in collaboration with Dr. Russell W. Raitt, of Scripps, and Dr. David G. Moore, of the Naval Undersea Center, San Diego. Preliminary results of cruise work as reported last year have been confirmed by continued analysis of geophysical data and extrapolation of stratigraphic control of Leg 22 of the Deep Sea Drilling Project into the geophysical section.

Briefly summarized, the Bay of Bengal sea floor first formed when India separated from Antarctica and Australia in early Cretaceous time, about 130 m.y. ago. Sea-floor spreading carried the Indian subcontinent northward as an isolated continent until collision with southeast Asia in Paleocene time, about 55 m.y. ago. Since that time, India has been pushing its way into and under the Asian continent, thus giving rise to the Himalayan Mountains, which have, in turn, shed huge volumes of debris to form the Bengal Deep-Sea Fan, now filling the Bay of Bengal. This continued underthrusting of the Indian Plate has resulted in sediment off-scraping and formation of the Indoburman Ranges, the Andaman and Nicobar Island Ridge, and the sedimentary island ridge off Sumatra. Since about Oligocene or Miocene time, the Andaman Sea has increased in width by formation of new crust, and has pushed the Andaman-Nicobar Island Ridge westward over the adjacent Indian Ocean floor.

Dr. Curray presented papers at invitational symposia at Princeton University in honor of Dr. Hollis Hedberg, and at the University of Wisconsin in honor of Dr. Marshall Kay. Both papers dealt with marine sediments, continental margins, and geosynclines.

Research programs of Dr. Edward D. Goldberg and his associates, Dr. Chih-wu Su, Dr. Kathe K. Bertine, Dr. Peter Liss, John J. Griffin and Minoru Koide, have been concerned with the transfer of materials from the continents to the oceans and with chemical reactions occurring within the ocean system. Emphasis has been placed upon those processes affected by the activities of man.

With Koide, Dr. Bertine, and graduate student Kenneth Bruland, the fluxes through the atmosphere to both glacial and coastal marine sediments of heavy metals were determined. In the Greenland glacier, there are larger amounts of sulfate being accumulated now than in earlier periods of this century. This increase is attributed to the combustion of fossil fuel. With the exception of mercury, cadmium, and possibly copper, the heavy metal distributions in these glacial waters are similar to those in atmospheric dusts. Only lead is unequivocally associated with man's activities. The anthropogenic fluxes of Pb, Cr, Cd, Zn, Cu, Ag, V, and Mo into the sediments of the San Pedro, Santa Monica, or Santa Barbara Basins have been determined. Paths from the continents include winds, sewer outfalls, storm run-off, and river run-off. At the present time, it is not possible to evaluate the contributions from each of these transporting agencies.

With Dr. Liss, a measure of the oxidizing potential of seawaters was sought through the ratios of iodide and iodate in seawaters.

With Bruland the development of the lead-210 dating technique for lacustrine and inshore marine sediments was continued.

With Dr. Su, measurements of chlorofluorocarbons in atmospheric and seawater samples were initiated to gain an understanding of the fates of these man-generated materials used in extensive quantities as propellant-solvents for aerosol dispensers.

With Koide and Bruland, radium and lead isotopes in highly productive Gulf of California waters were assayed by novel techniques. Both appear to have their concentrations governed by the intense biological activity, and their residence times in surface waters are calculated to be of the order of months, very low compared to those in open ocean waters.

With Griffin, the intensities of forest and chaparral burning in coastal areas of Washington and California were sought through the rates of accumulation of soot (elemental carbon) in coastal sediments. Following burning, the fire debris is transported about the environment by winds. On the basis of the fluxes of this soot of the Saanich Inlet (Puget Sound) and Santa Barbara Basin deposits, it appears that only in the former case does there seem to have been substantial changes over the past century. The fluxes of carbon to Saanich Inlet appear to have nearly doubled over the past several decades, perhaps as a result of man's involvement in wood burning.

The main research activities of Dr. James W. Hawkins and students working with him have been directed toward understanding the evolution of the oceanic crust, island arcs, and linear volcanic chains in the Samoa-Fiji-Tonga area of the southwest Pacific.

A revised bathymetric chart of the Lau Basin has been finished as have maps showing sediment thickness and magnetic field intensity. The geochemistry and petrology of seamounts located at the north edge of the Tonga Trench, the Samoan Island chain, and the Louisville Ridge have been studied and used to help interpret crustal evolution and the relationship of these features to the regional tectonic framework.

The Louisville Ridge appears to be a linear volcanic chain, much like the Emperor-Hawaii chain, rather than an extension of the Eltanin Fracture Zone, as suggested by previous studies by other workers. The Samoan chain and adjacent seamounts probably owe their origin to rupture of the Pacific Plate as it is sharply flexed downward into the north end of the Tonga Trench.

The research of Dr. Miriam Kastner has included the following projects:

(1) Research on kinetics of montmorillonite to illite conversion, hydrothermally at 118° and 136° C in potassium, sodium, and aluminum chloride solutions of various concentrations is still in progress. Dr. Jeffrey L. Bada was a co-researcher.

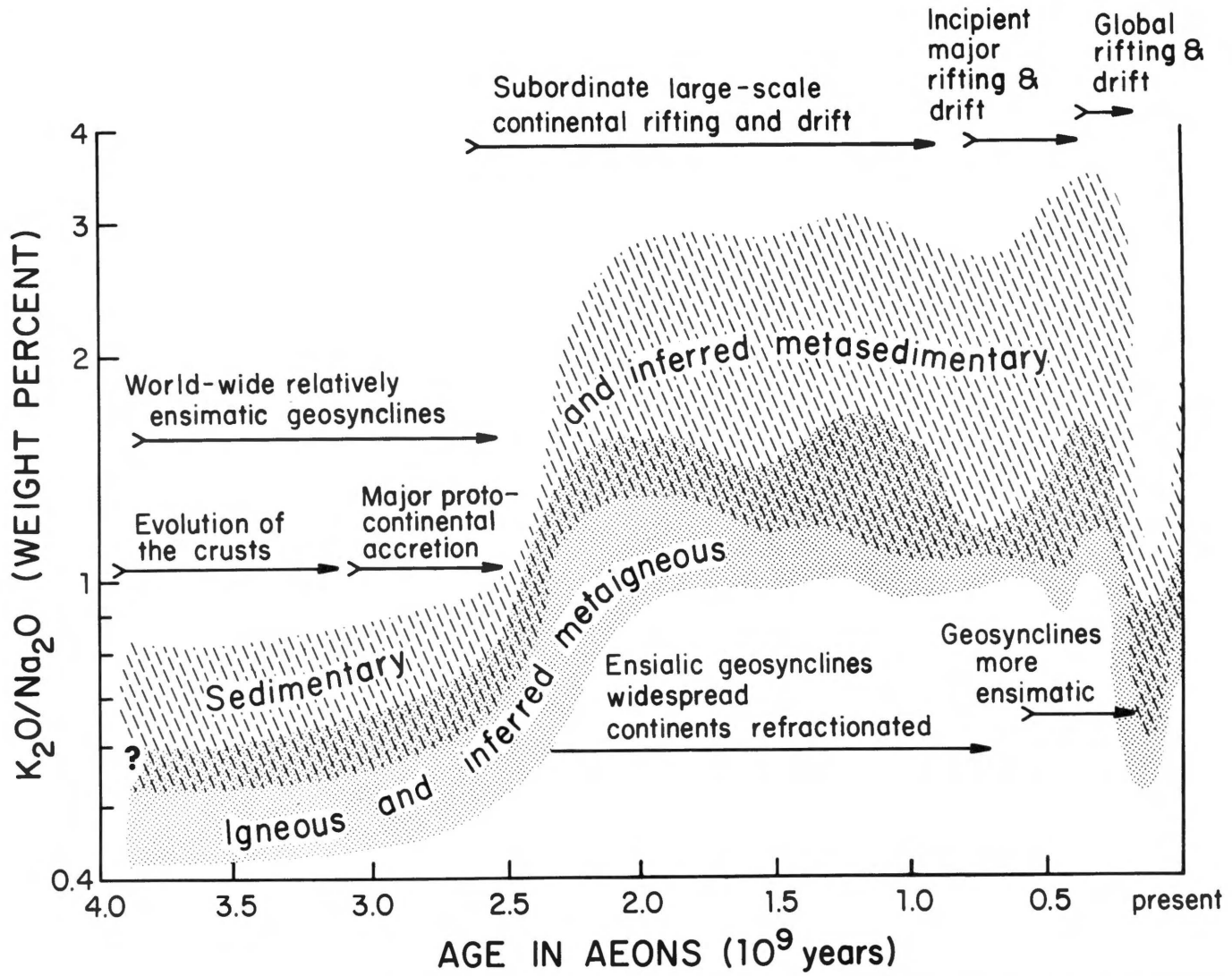
(2) The origin of cherts, in particular, cherts from Deep Sea Drilling Project cores. John B. Keene, who is concentrating on this project for his doctoral thesis, participated in DSDP Leg 32. Chert, porcellanite, and siliceous sediments were sampled from seven sites of the northwest Pacific. The studies strongly indicate that recrystallization of amorphous radiolarian tests to opal-CT and microquartz are enhanced whenever carbonate is the associated sediment. Keene and Dr. Kastner studied the origin of thin, porcellanite layers in a pelagic, montmorillonitic, brown clay from deep-sea core No. SCAN 16P (16° 25'N, 164° 24'W). The study showed that the source of some silica is the transformation of montmorillonite to hydrous mica.

(3) Origin and diagenesis of deep-sea zeolites. Sharon Stonecipher is concentrating on this project for her doctoral thesis. She made a survey of DSDP data and examined the X-ray data for the presence of zeolites and coexisting minerals. She also recorded age of zeolite-bearing sediments, sedimentation rates, burial depth, and geographic distribution.

Dr. Jacqueline Mammerickx completed nine of a series of 11 charts on the bathymetry of the South Pacific in collaboration with Stuart M. Smith, Isabel L. Taylor and Thomas E. Chase. Magnetic data were analyzed concurrently by Drs. Peter Molnar, Tanya Atwater, Roger N. Anderson and Henry W. Menard, and these led to a new assessment of the Cenozoic history of the South Pacific.

Investigation of radiolarians in cores collected during the early phases of the Deep Sea Drilling Project provided a general description of the Tertiary stratigraphy of these microfossils. In examining sequences from different biogeographic regions in greater detail, William R. Riedel and Annika Sanfilippo have found that the late Tertiary sequence in the western Indian Ocean differs significantly from that in the Central Pacific. Nevertheless, there are sufficient similarities to permit failrly detailed correlations between these two areas, and with the Mediterranean.

As a result of taking current-meter records simultaneously at various depths along the axes of submarine canyons and at various heights above canyon floors, Dr. Francis P. Shepard has established that the currents are caused primarily by internal waves that advance for the most part up the axes of canyons toward shore. In deeper



Variations in petrogenic index K_2O/Na_2O of igneous, sedimentary, and metamorphic rock complexes plotted as function of geologic time. Variations in crustal environments of constituent rocks, as indicated by index, and by related lithologic features, rock associations, and relative abundances, suggest crude first-order sequence of crustal evolution and global tectonics.

A. E. J. Engel

water, the alternation of these currents between up- and down-canyon periods is closely related to the tides, but, near the canyon heads in relatively shallow water, much shorter periods are recorded, possibly caused by reflection of the internal waves at the canyon heads. A striking characteristic of the currents is that they often have roughly synchronous motion from near the floor to as much as 30 m above the bottom. Although currents usually move along the axes, many flows are almost directly cross-canyon. These flows may last for several hours and may have as high velocities as those that follow the axes. Cross-canyon winds may explain some of the cross-canyon flows, and the tide appears to have some influence.

Dr. Ray F. Weiss, continuing his participation in the GEOSECS program, served aboard the Woods Hole Oceanographic Instituiton's R/V *Knorr* as an associate chief scientist on Leg 2 in the Greenland and Norwegian seas and on Leg 4 in the western equatorial Atlantic. During the austral summer, Dr. Weiss conducted a geochemical sampling program aboard the U. S. Coast Guard icebreaker *Glacier* in the Weddell Sea. This work was carried out in conjunction with the physical oceanographic studies of Dr. Theodore D. Foster, of Scripps, and it made possible the extension of GEOSECS sampling for chemical, isotopic, and radioisotopic tracers into this most important region of Antarctic Bottom Water formation.

GEOSECS

GEOSECS is an acronym for Geochemical Ocean Sections Study, a multi-institutional program funded by the International Decade of Ocean Exploration section of the National Science Foundation. Two GEOSECS groups are in residence at Scripps: the GEOSECS Operations Group, directed by Arnold E. Bainbridge and located in Sorrento Valley, and Dr. Harmon Craig's laboratory group on the campus. Dr. Craig is a member of the GEOSECS Executive Committee, which directs the program. Joseph L. Reid of Scripps is a member of the program's Scientific Advisory Council.

During 1972-73, the Atlantic GEOSECS Expeditions were carried out aboard R/V *Knorr* of Woods Hole Oceanographic Institution. The expedition program consisted of nine legs that extended from well north of Iceland, down the western Atlantic to Cape Horn, across the Antarctic to Capetown, up the eastern side of the South Atlantic, and with an east-west section across the Atlantic and back to Woods Hole. Dr. Craig was chief scientist on Leg 4 in the Equatorial Atlantic and on Leg 7 in the Antarctic. Reid was chief scientist on Leg 8 from Capetown to Dakar. Drs. Ray F. Weiss and Yu-chia Chung, both of Scripps, served as scientists on Legs 4 and 10, and Bainbridge on Legs 1 and 3.

Aboard R/V Knorr, *which worked Atlantic GEOSECS out of Woods Hole Oceanographic Institution during 1972-73, a computer utilized four electronic screens to display data telemetered from two underwater, instrumented sampling packages. GEOSECS Project Director Arnold E. Bainbridge, of Scripps, here sits at a console and is able to study, in real time, the* in situ *distribution of temperature, salinity, oxygen, and light scattering, as well as several computed parameters, such as water density. Two computers, plus automated equipment, provided a precise, rapid, on-board calculation of data such that they were ready for distribution to GEOSECS principal investigators two weeks after the end of each leg of the expedition. Scripp's R/V* Melville *was being prepared during the year for Pacific GEOSECS, which was scheduled to leave San Diego in August, 1973, for ten months at sea.*

A complete set of the Atlantic GEOSECS Leg Reports, including all shipboard measurements (salinity, temperature, oxygen, nutrients, total CO_2, alkalinity, gas chromatography, and radon) and the detailed Salinity-Temperature-Depth (STD) profiles from surface to bottom at each station, is on file in the SIO Library at Scripps, where it may be consulted. Atlantic results to date, including C^{14} and tritium data, will appear shortly in the special GEOSECS issue of *Earth and Planetary Science Letters*. It will be the third collection of GEOSECS papers this journal has published.

Marine Biology Research Division

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

In the saline marine environment, fresh water is a problem. As with desert animals, many marine organisms that have adapted to high fat diets get some of their water from metabolic processes. In the temperate, polar, and deeper parts of the sea, wax ester is a major nutrient and a stored source of metabolic energy. The fats of algae (phytoplankton) are converted to liquid wax by copepods small enough to graze these microscopic plants. A group of biochemists working with Dr. Andrew A. Benson has examined the role of wax in the energy-transfer processes of the food chain. Invariably, animals living under threat of starvation store and utilize wax as a long-term energy supply. Copepods living near the North Pole accumulate up to 70 percent of their weight as wax ester to survive the ten months of starvation and darkness.

Although wax is not a normal human food, it is a source of energy important for herring, sardines, and many other small fish. The physiological adaptations to high wax diets are being investigated in order to ascertain special adaptations in digestive activities.

In an expedition on the Great Barrier Reef, Dr. Benson observed small reef fishes ingesting the mucus exuded by corals. The mucus was found to contain wax ester, which is also a major storage material in tropical corals. This transfer of energy-rich material from coral to fish provides a newly recognized pathway in the tropical reef food chain. The extent of this transfer is under investigation. The mass of wax accumulated by corals appears to be a food source for the Crown-of-Thorns starfish responsible for much damage in South Pacific reefs. The starfish possesses very active wax digestive enzymes.

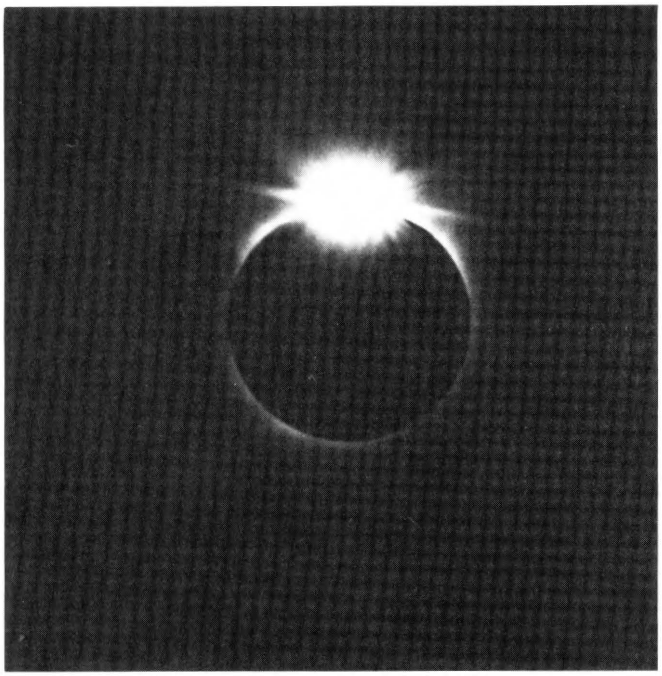
Experiments to explain regulation of calcification in marine organisms suggest that monomolecular layers of lipid and other compounds act as inhibitors of calcium carbonate crystallization. Their removal and consequent regulation by coral or clam enzyme systems is under study.

Pollution of marine waters by petroleum and other hydrophobic materials leads to complications in the natural processing of oils and lipids by marine organisms. Pollution of coral mucus and fish body mucus which is consumed by many mucous feeders, can insert some noxious substances into the marine food web. The extent of this process is being studied by the use of radioactively labeled petroleum components. The relation of petroleum metabolism to that of the naturally produced 21-carbon hydrocarbon of diatoms is of considerable interest.

Earlier studies in Dr. Benjamin Volcani's laboratory showed that silicon, thought to be biologically inert, is, in fact, required for fundamental metabolic processes in the diatom. In the last five years, it has been established by other investigators that silicon is not only essential for bone formation in mammals and chicks, but is strongly implicated (particularly as asbestos) as a causative agent in some forms of human cancer, possibly because of the ability of silicic acid to disrupt certain cell membranes. The current focus of research of Dr. Volcani and his associates is, therefore, to uncover the metabolic and biochemical mode of action of silicon within the cell, using the diatom as a model experimental system. It is hoped such studies on the diatom will provide guidelines to understanding the biochemistry of silicon in the more complex animal systems.

In a major project, Dr. Cornelius Sullivan developed a method for isolating the plasma, endoplasmic reticulum, and Golgi membranes and the mitochondria of the diatom *Nitzschia alba,* and analyzed their morphological, chemical, and enzymatic composition. In general, the diatom membranes are chemically similar to those of higher plants and animals, but differ in the high specific carbohydrate content of the smooth membrane. Particularly interesting was the discovery that plasma membranes of the diatom contain a synergistically stimulated $(Na^+ + K^+ + Mg^{2+})$-ATPase, an enzyme similar to a "transport" ATPase found in animal cells. Eight different ATPase activities were found in the membrane preparations. This work opens the way for *in vitro* studies of the role of membranes in transport, translocation, and transformation of silicic acid.

In another extensive study, Dr. Charles Mehard investigated the uptake dynamics of radiolabelled silicic acid and the chemically similar germanic acid. Both *in vivo* and *in vitro* $^{31}Si(OH)_4$ and $^{68}Ge(OH)_4$ are actively taken up by diatom and rat-liver mitochondria, and this process is inhibited by respiratory inhibitors and uncouplers. Uptake and accumulation of both elements were also similar in



Photograph of "diamond ring" period of total solar eclipse taken June 30, 1973, by Prep. Cadet George E. Early from aboard Texas Clipper *positioned some 40 miles north of Santa Antao in Cape Verde Islands off Mauritania. Scripps research biologist Dr. Elizabeth Kampa Boden was a guest aboard ship to conduct research on vertical migration of marine animals.* Texas Clipper *is a Texas A&M University cadet-training ship. Cadet Early is from Avenger, Texas.*

George E. Early

heparinized blood, liver, spleen, and kidney tissues of rats. For *in situ* localization of silicon in organelles with electron microscope-electron probe microanalysis, a freeze substitution technique for diatom and tissue specimens was devised to prevent leaching of the element during preparation.

In other studies, graduate student John Paul has characterized the enzyme system (glycolate:O_2 oxidoreductase) in the diatom *Thallassiosira pseudonana,* which oxidizes glycolic acid, an important photosynthetic product, and he is exploring its occurrence in other diatoms. As previous studies in this laboratory have shown that silicic acid is involved in DNA synthesis, Thomas Okita is investigating in detail, for his doctoral thesis, the role of silicon in the replication of DNA and its effects on specific enzyme systems.

Dr. Volcani and colleagues at the Tenovus Institute for Cancer Research, Welsh School of Medicine, Cardiff, Wales, are collaborating on a long-term study to see whether talc is, as has been suggested, implicated in human cervical and ovarian cancers.

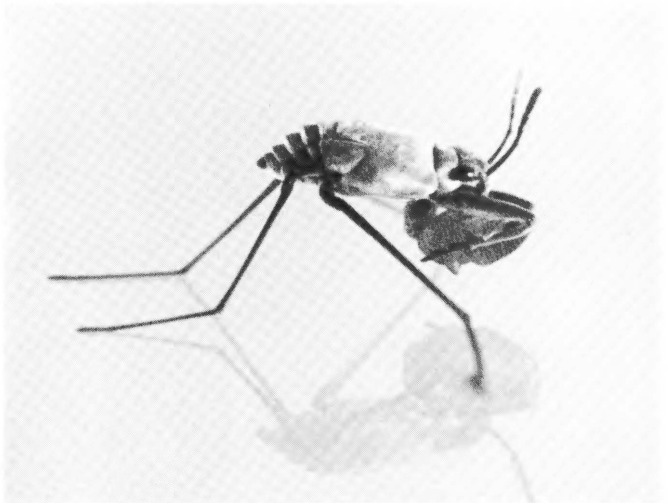
The element lead — long known as a cumulative poison for the human system — is still being volatilized in large quantities by automobiles, and transported, by wind and rain, to the fresh and marine waters of the ecosystem. Phytoplankton, the primary producers in aqueous environments, is potentially vulnerable; hence, the need to study effects of lead on representative examples of microscopic marine algae under controlled conditions. Dr. Ralph A. Lewin and his colleagues, notably Dr. Anita Hessler and Linnea Dayton, have investigated not only short-term toxicity and viability effects, but also possibilities that lead may be a mutagen (so far, fortunately, with negative results, at least for the green flagellate *Platymonas*) or an agent capable of changing the population structure in mixed cultures (in which it was found that the diatom *Phaeodactylum* tends to detoxify the medium for associated Platymonas cells).

Experiments are also being carried out on *Flexibacter polymorphus,* a filamentous marine bacterium that can glide over solid substrata at rates of up to 8 mm/sec. Although the mechanism of gliding movement is unknown, it is suspected that sub-microscopic, goblet-shaped particles located on the surface of the cell envelope, may be involved in this process. These sub-units are roughly 25μm in diameter, and are composed of several smaller protein-containing sub-units, currently being studied by Harry Ridgway, a graduate student in Dr. Lewin's laboratory.

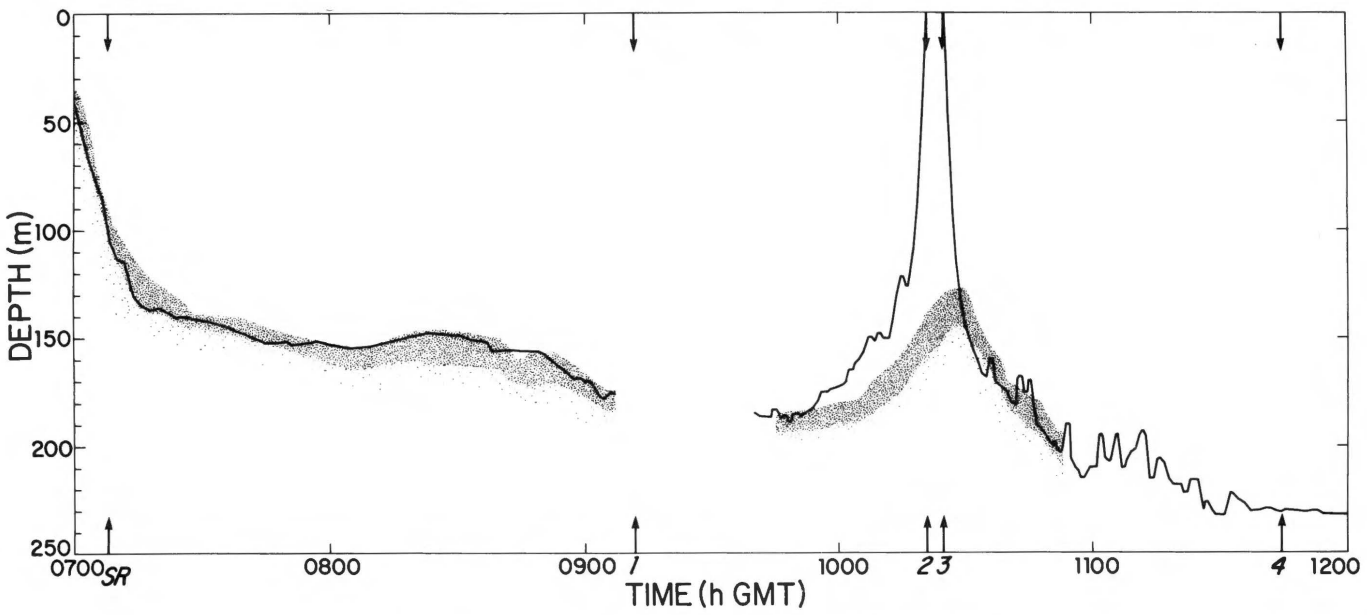
During studies conducted by Dr. Lewin in the Central Pacific Gyre, he developed a modification of the "minimum probable number" system for enumerating oceanic bacteria. Very dilute nutrient media (calculated not to offend the sensitivities of the most oligotrophic microbes) were used and, after a few days' incubation, droplets were "plated" on an agar medium of similar composition. Inexplicably, he found almost 10 percent of the bacteria capable of digesting agar, though the nearest-known source of that algal product was around the Hawaiian Islands, many hundreds of km away.

At the invitation of UNESCO, Dr. Lewin directed a four-week course in experimental microbiology at Nanyang University, Singapore, for selected representatives from some 11 "underdeveloped" countries of southeast Asia, where "development" is bringing in its wake problems necessitating microbiological study: contamination of inshore waters by sewage, industrial wastes, spilled oil, and others. A printed report, which he edited jointly with Professor Anne Johnson of Nanyang University, summarized the variety of research projects carried out by the participants.

Enrichment cultures of marine bacteria that degrade various crude oils and petroleum products have been shown by Dr. Claude E. ZoBell to contain up to two or three dozen different species. Pure cultures consisting of single species were found to oxidize only a narrow range of hydrocarbons normally present in petroleum. The degradation of a given hydrocarbon is only rarely completed by any one pure culture. Several species acting together on oil degrade it more rapidly and much more completely than the total action of a like number of pure cultures acting alone. Whereas pure cultures tend to oxidize hydrocarbons to aldehydes, alcohols, organic acids, and other primary oxidation products, mixed cultures consisting of a number of species tend to convert hydrocarbons mainly to carbon dioxide, water, and bacterial cell substance. The greater effectiveness of mixed cultures in degrading oil has been shown to be caused by (a) the co-oxidation or co-metabolism of certain components, (b) the tendency of some species to emulsify oil in water, thereby rendering it more susceptible to oxidation, and (c) the action of certain species on primary and secondary oxidation products of hydrocarbons.



The oceanic insect Halobates *is seen here standing on the water, its prey a wingless* Drosophilia*, a small fly. Tens of thousands of genera of insects are known on land; there is only one on the sea:* Halobates. *Biologist Lanna Cheng, of the Marine Life Research Group, brought scores of these "sea skaters" back to Scripps aboard R/V* Thomas Washington*, during South-Tow Expedition.*



Vertical distribution of the $2x10^{-1}$ $\mu W/cm^2$ /nm isolume during the hours between sunrise and end of the June 30, 1973, total solar eclipse: solid line. Vertical position of the sonic-scattering layer observed at same times is indicated by stippling. Gap in record was occasioned by removal of ship, Texas Clipper, *for more propitious observational positioning. Vertical arrows indicate SR, sunrise;* 1 *and* 4, *first and fourth contacts, the beginning and the end of eclipse;* 2 *and* 3, *beginning and end of totality.*

Elizabeth Kampa Boden

The beginnings of embryonic life are being studied by Dr. David Epel and his colleagues. Their research on the easily studied sea urchin egg provides basic information applicable to the embryonic development of all organisms. Recent research has concentrated on the mechanisms of activation of development that attend fertilization and on the mechanisms of exclusion of supernumerary sperm during fertilization.

Work on the activation process has revealed that there are two types of control processes operative in fertilization. An early process, beginning within seconds of insemination, initiates a sequence of changes that are causally linked to each other. A late process, beginning at five minutes after insemination, initiates a different sequence of independent and causally unlinked processes. Research with Dr. R. A. Steinhardt of UC-Berkeley indicates that the primary, early change is a release of intracellular calcium. Comparative studies with eggs of annelids, molluscs, tunicates, and vertebrates indicate that such $Ca^{+}2$ release is a general occurrence. Other research by two sabbatical investigators, Dr. Christopher Mathews and Dr. Richard Crawford, concerns control of DNA synthesis and Na^{+}/K^{+}-ATPase during early development.

The mechanisms of exclusion of supernumerary sperm are being examined by Dr. Edward Carroll and Mia Tegner. Dr. Carroll has recently purified the proteases released by eggs at fertilization, and is examining the properties of this enzyme in relation to its role in the block to polyspermy.

A highlight in the research program of Dr. Carl L. Hubbs during the year was the completion of the extensive memoir on "Hydrographic History and Relict Fishes of the North-Central Great Basin" (*Memoir,* vol. 7, of the California Academy of Sciences). Diagnoses of the new fishes involved were published. During three trips to Latin America, Dr. Hubbs continued revisionary studies of the eastern Pacific fish fauna, at laboratories in Peru and Costa Rica. He and his colleagues conducted a cruise (MV-73-1) from La Paz, Baja California, to Punta Arenas, Costa Rica. Extensive collections and observations were made by the party on the fish fauna of the oxygen-minimum layer. This was measured repeatedly and found to harbor spectacularly dwarfed fishes of a half-dozen groups. Visiting associates on this trip conducted a very extensive survey of the parasites of the fishes, and collaborated in observations on the marine fishes, birds, and mammals encountered. Large, quantitative collections were made of littoral to bathybial, bottom, mid-water, and surface fishes and invertebrates. Collections of hagfishes were particularly significant for Dr. Hubbs's world revision of the group, which was also extensively furthered by local collecting and by systematic analyses of the species of the eastern Pacific and of other seas.

Progress was made on the annotated list of the fishes of California, now to include an analysis of the rich fauna, and research was continued on the marine mammals of the Eastern Pacific. Robert L. Wisner continued his general review of the lanternfishes of the eastern Pacific, which will be published by the Navy.

In the laboratory of Dr. Theodore Enns, studies continue on the transport mechanisms of water, electrolytes, and respiratory gases in intact animals, plants, and tissue preparations. The action of the enzyme carbonic anhydrase in the photosynthetic production of marine plants, the first step in the support of all ocean life, is under investigation. The enzyme has been detected in all species of marine algae tested, and reduction in growth resulting from its inhibition has been demonstrated in some saltwater plants.

Gary H. Dobbs, III, is studying kidney function of Antarctic fish under the guidance of Drs. Arthur L. DeVries, George N. Somero, and Theodore Enns. Light and electron microscopy of tissue samples collected while he was on an expedition with Dr. DeVries at McMurdo Sound, Antarctica, has shown that these animals possess a unique mode of urine formation found in only a few other vertebrate species. Urinalysis reveals the kidney of Antarctic bony fishes to be a powerful transporting epithelium with the ability to concentrate magnesium in the urine in amounts 200 to 300 times the levels in blood plasma.

Dr. Denis L. Fox has continued his researches, in cooperation with staff members of the San Diego Zoo, on the occurrence and metabolism of carotenoid in waterfowl. A study was completed concerning the genetic dominance of red carotenoid pigmentation in the colorful Caribbean flamingo *Phoenicopterus ruber,* over that of its pale, related species, *P. antiquorum,* the European, or Greater,

flamingo. A hybrid male bird, resulting from an adventitious cross-mating between a *P. ruber* hen and a *P. antiquorum* male, expresses the bright red, overall feather pigmentation of its mother, in contrast to the whiteness of the sire. He is able, like the sire, and in contrast to the hen, to mobilize *one* rare carotenoid, phoenicopterone, from the blood into the flight-feathers, along with three other carotenoid fractions common to feathers of both species.

Ned Ruby, a graduate student working under the supervision of Dr. Fox, has been studying the adaptations of the red, sand-dwelling, shore polychaete annelid worm *Euzonus mucronata* to changes in temperature and in oxygen tension that prevail in the rather exposed environment. The animals' adaptations show some unusual characteristics of tolerance.

In the laboratory of Dr. George Somero, studies of molecular mechanisms of environmental adaptation focused on a variety of phenomena. Work with Philip S. Low revealed important differences in the activation thermodynamics of enzymic reactions catalyzed by interspecific varients of the same enzyme. Enzymes from low-cell-temperature organisms were more efficient than the homologous enzymes of birds and mammals in reducing the free energy of activation "barriers" to metabolic reactions. It was further observed that enthalpies and entropies of activation vary in a "compensatory" manner. This observation permitted deduction of a potential mechanistic basis for the observed differences in catalytic efficiency between enzymes of high- and low-temperature species. Structural studies are now being pursued to determine the underlying differences in primary, secondary, and tertiary structures among these enzymes that might account for their functional differences.

In joint work with Dr. Michael Soule of the UCSD Department of Biology, Dr. Somero examined the relationship between enzyme polymorphism and environmental temperature variability. Using marine teleost fishes from either very stable thermal regimes, such as the Antarctic seas and the deep ocean, or from highly variable habitats, such as estuaries and tide pools, they found that organisms that must cope with wide ranges of temperature on a diurnal or seasonal basis do not have more complex isozyme and allozyme systems than stenothermal species.

This finding contradicts predictions made by many population biologists and evolutionists who have suggested that high levels of genetic and protein polymorphism are of advantage to species that encounter environments varying widely in time and space.

Bonnie Jean Davis continued her graduate studies of enzyme polymorphism in fishes of the genus *Gibbonsia*. Differences were noted in a number of enzyme parameters, including inter- and intraspecific differences in the levels of allozyme polymorphism.

In conjunction with Low and John G. Duman, studies were intitiated of the structural and functional differences between homologues of given enzymes which are adapted to widely different conditions of salt composition. These investigations are focusing on kinetic and amino-acid composition differences among homologues of an enzyme to determine the important adaptations which suit an enzyme for optimal function under the particular conditions of salinity it experiences in the intracellular environment.

Dinoflagellates are among the dominant components of the ocean's phytoplankton. On the positive side, they contribute significantly to marine photosynthesis and are food organisms for larval fish and invertebrates; on the negative side, red tides of certain species are associated with the production of toxins which are injurious to marine organisms and pose a health hazard to man. Aspects of both photosynthesis and toxin production of dinoflagellates are under study by Dr. Francis T. Haxo and his associates as they take advantage of the extensive micro-algae culture collections at Scripps and the generosity of other investigators in providing desired species.

In collaboration with Dr. Henry Rapoport, of UC-Berkeley's Department of Chemistry, Dr. Haxo and James Lance have undertaken a long-term study of toxin production by suspect dinoflagellates, such as *Gonyaulax polyedra, G. tamarensis,* and *Gymnodinium breve.* Initial efforts have been directed toward the devlopment of a sensitive, rapid and specific chemical test for saxitoxin and the reality of toxin production by *Gonyaulax polyedra,* the common, red-tide dinoflagellate of Southern California waters.

The question of what chloroplast pigment components comprise a "typical" dinoflagellate has been a major thrust of the research by Dr. Haxo and his collaborators. Together with Dr. Shirley Jeffrey (on sabbatical leave from the Marine Biochemistry Unit, CSIRO, Sydney, Australia) and Margarete Sielicki, they examined 22 dinoflagellates, concentrating on broad pigment patterns. The "typical" dinoflagellates (reflected by the patterns found in 18 species) contain (1) peridinin, as the major xanthophyll; (2) diadinoxanthin, dinoxanthin, and a variable number of unknown minor xanthophylls; (3) B-carotene, as the sole carotenoid hydrocarbon; and (4) two chlorophylls, chlorophyll *a* and chlorophyll c_2 only.

An atypical pattern was found in four other dinoflagellates in that fucoxanthin replaced peridinin (also reported by other workers), and that both c_1 and c_2 types of chlorophyll *c* were present. The latter feature first noted in *Peridinium foleacium* by Nancy Withers, a graduate student, lends support to the idea that such dinoflagellates are in reality symbiotic associations of a "colorless" dinoflagellate and a photosynthetic endosymbiont belonging to a different phyletic group.

A highlight in Dr. Elizabeth Kampa Boden's researches was her observation of the movements of mesopelagic animals during the total solar eclipse, June 30, 1973. Such rare events — the next eclipse of similar magnitude will occur in 1991 — afford the photobiologist the unparalleled opportunity to determine the effect of sudden, unprecedented withdrawal of light from the natural daytime environment on the behavior of animal communities whose vertical migrations are known to be photoregulated.

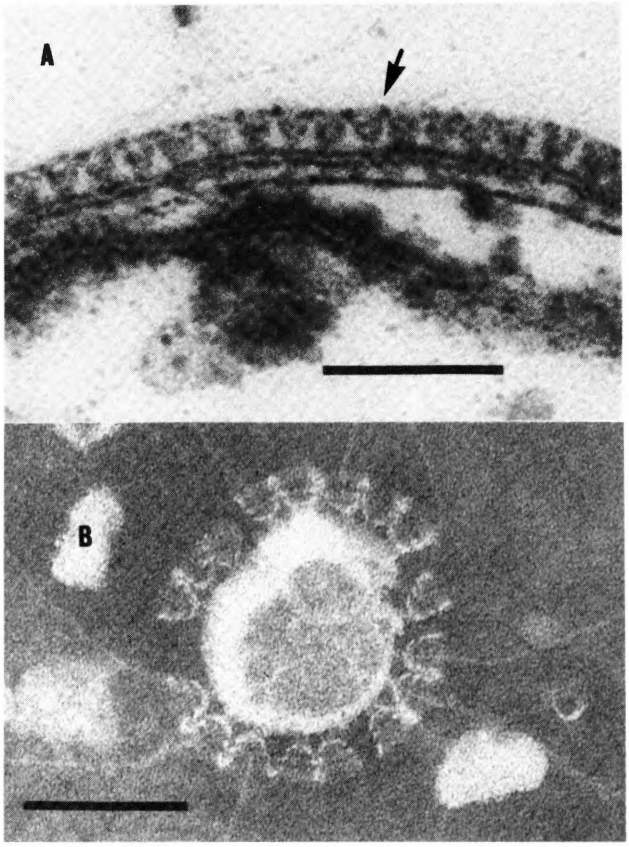


Fig. A — Electron micrograph of thin section of lysed cell of Flexibacter polymorphus *showing goblets (arrow)* in situ *on surface of outer cell membrane. Marker equals 1,000 Angstroms. In Fig. B, electron micrograph shows fragments of the outer membrane from a purified preparation, with goblets still attached; negatively stained with phosphotungstic acid. Marker equals 1,000 Angstroms.*

Marine Biology Research Division

Dr. Boden worked aboard the Texas Maritime Academy's T/V *Texas Clipper* at a station north of the Cape Verde Islands, in the middle of the path of eclipse totality. Direct measurements of photoenvironment made with a bathythermo-irradiance meter and observations of a sonic-scattering layer displayed by a Ross Laboratories 200 kHz echo sounder during the hours between dawn twilight and the end of the eclipse showed that the vertical position of the scattering layer community was closely associated with the vertical position of an isolume of $2x10^{-1}$ $\mu W/cm^2/nm$ at 470 nm (see illustration). At 0940 h GMT, 2½ h after sunrise and 26 min after the moon's shadow had begun to obscure the sun, the scattering layer began to rise in the water column. Its upward movement was most pronounced during the nearly four min of totality and achieved a maximum velocity of 3 m/min. Shortly after the end of totality, the animal community began to descend again, and within 20 min it had resumed its association with the isolume.

Dr. Boden concludes that the animal community tried to stay within its optimal photoenvironment during an abnormal withdrawal of light, but that it simply could not achieve the optimum because of its physical inability to swim fast enough.

Dr. Nicholas D. Holland, while on sabbatical at the Plymouth Laboratory in England, has been continuing ultrastructural investigations on oogenesis and fertilization in crinoids. Ongoing work in his laboratory has concerned cell renewal in the protochordates and scanning-electron-microscope studies on development of starfish embryos.

Marine Life Research Group

The Marine Life Research (MLR) program during the past quarter century at Scripps has included a spectrum of research activities. MLR's participation and goals in the CalCOFI program (California Cooperative Oceanic Fisheries Investigations) was defined in last year's annual report, which described some of the major MLR research being carried out in the varved sediments of the California Current, deep-sea photography, current measurements, deep circulation, and the North Pacific Study.

Discussed below are current biological studies being carried out by MLR under the directorship of John D. Isaacs, including pelagic communities, phytoplankton, sea-surface biology, mid-water and benthic fish, euphausiids, and copepods. Next year's report will cover studies of the deep scattering layers, a food-web theory, drift bottles, and the wave-powered generator; these are not reported at this time in the interest of brevity.

Pelagic communities. Drs. Elizabeth Venrick and Lanna Cheng, with members of the Food Chain Research Group (FCRG) of the University of California's Institute of Marine Resources (IMR) headquarted at Scripps, are participating in a program directed by Dr. John A. McGowan to describe, quantitatively, the community structure and food chain relationships of the open ocean system near the axis of the North Pacific Central Gyre. Further, the group is working to define as rigorously as possible the physical-chemical variables of the habitat. (Details of the FCRG participation are reported in the section on IMR activities.)

The group carried out extensive studies of the California Current, an area of extremely complex and changeable structure and function. They have chosen the gyre as a much simpler area for a first attempt at a multidisciplined approach. The central gyres of the Pacific are particularly appropriate for these studies because, based on the open ocean area, they best approximate closed systems — a fundamental condition for ecosystem analysis in its present development.

The data so far collected have established that during the summer months the relative proportions of abundances of macrozooplankton and mesopelagic micronekton species are less diverse and more stable than in the California Current. The total biomass of zooplankton has remained fairly constant during most summers, but the biomass of mesopelagic and bathypelagic micronekton has varied significantly both in terms of numbers of individuals per species and the average size of individuals within species. The chlorophyll distribution shows a persistent and almost continuous maximum at about 110 m. This is *below* the traditionally defined euphotic zone, but, nevertheless, it is functional, judging from *in situ* measures of productivity. The productivity peak is much shallower, and there have been year-to-year significant differences in standing crops of chlorophyll associated with large-scale meteorological events. The changes in biomass of mesopelagic and bathypelagic nekton are associated with variations in chlorophyll; however, the zooplankton standing crops have remained relatively constant.

Phytoplankton. Dr. Venrick has conducted research in the seasonal and long-term fluctuations in the species' composition of the first trophic level of the gyre. Additional studies include small-scale fluctuations of the phytoplankton abundances and their implications for sampling, and the composition, formation, maintenance, and dynamics of the deep chlorophyll-maximum layer that underlies the euphotic zone of the Central Pacific at a depth of 110-130 m.

Biology of the sea surface. Dr. Cheng is carrying out research on organisms living at the air-sea interface, a highly specialized community in the marine environment (pleuston or surface neuston). The major organisms found in this layer include the Portuguese man-of-war (*Physalia*), the by-the-wind-sailor (*Velella*) and other siphonophores, the purple snail (*Ianthina*), and eggs and larvae of several families of fish. On the sea surface itself, only the "sea skaters" (marine insects in the genus *Halobates*) occur. Although some of these organisms are well known by name, very little is known about their biology or their special adaptations to cope with changes in physical and chemical properties at the air-sea interface. Dr. Cheng has collected neuston samples from the North Pacific Gyre for studies of community structure and estimates of biomass. During two of the 1973 CalCOFI cruises, neuston cruises, neuston samples were collected specifically for community structure studies; they are currently being sorted to major animal groups.

Mid-water and benthic fish. Tetsuo Matsui, in collaboration with Dr. Richard Rosenblatt, is studying the taxonomy and distribution of the mid-water fish family Searsidae, and the life history of the rattails (or grenadiers), *Coryphaenoides acrolepis*.

Study of the gill filaments of the family Searsidae indicates that the distribution of the species is influenced by oxygen concentration.

Setline data on rattails collected during a cruise (February 28-March 2, 1973) seem to indicate that sexual segregation in the female-dominant area of the San Diego Trough breaks down during the spawning period (28 females to 20 males). Prior to this the records show the females dominating the catch over the flat part of the troughs and the males dominating the escarpment. Males were still dominant (22 males to one female) over the escarpment during that cruise. This seems to indicate a movement of males into the female territory during spawning.

Euphausiids. Dr. Edward Brinton and his associates have been working with problems in zoogeography, life histories, and comparative morphometry of euphausiid and sergestid crustaceans. A clearer definition has been gained of the mechanisms, both intrinsic and environmental, that act to maintain or conserve populations. Studies have been made of the dynamics of the environments of the California Current, the Indian Ocean, and a transition zone in the tropical South Pacific. More recently some Atlantic species and their habitats have been compared.

The importance of euphausiids in the economy of the sea stems partly from the fact that these crustaceans are omnivorous feeders that consume diatoms, zooplankton, and detritus. In addition, the bulk second to the copepods as a stock of basic animal protein, if the larger protozoans are excluded from consideration. Euphausiids serve as fodder plankton and form a part of the diets of many commercially important fishes, including both filtering and predaceous species. They are known as "krill" — the principal food of the baleen whales, particularly in northern and southern seas where euphausiid populations frequently form into great swarms at the surface. In tropical or subtropical oceanic waters, such swarming has been rarely noted.

Much of the data now compiled has been applied to evaluating differences between the animals of distinguishable populations of the same or similar species. Thus insight has been gained into the genetic

specificity of the taxonomic entities being dealt with, and the pathways along which morphological and geographical divergence may have occurred. Recognition and interpretation of levels of population specificity have provided the basis for meaningful systematic status, that which reflects as much of phylogeny as possible.

Of particular interest is Margaret Knight's identification of a curiously ornate, relatively large, and quite common metanauplius, long a mystery to specialists in the plankton of the Indian Ocean and the Pacific, as a developmental stage of the euphausiid *Thysanopoda tricuspidata*. She has prepared detailed descriptions of the stages of this species that provide evidence for a different relationship of the species to others in the genus, than had been assumed. Similarly, her work on larval development in *Euphausia* is yielding new evidence on intragenetic phylogeny.

Dr. Brinton has directed analyses of plankton samples and environmental data from two cruises (opposite seasons) he carried out along transects of an equatorial-subtropical region of the mid-South Pacific. These have provided three-dimensional data on the structure of northern and southern plankton populations abutting this east-west zone itself. Work is in progress to obtain as fine a definition as possible of the local zoogeography across this abrupt gradient from fertile to barren water.

The zoogeography of Indian Ocean euphausiids has been studied by Dr. Brinton extensively. The species have been mapped and research continues on such processes that affect the distributions: seasonal variability in population structure (based on recognition and enumeration of early larval stages), comparisons with hydrographic data, and resolution of taxonomic problems.

Copepods. Drs. Abraham Fleminger and Kuni Hulsemann have been examining a large collection of epiplanktonic zooplankton samples representing all oceans and adjacent seas of the world lying between 60°*N* and 60°*S* latitudes to establish the number and geographical distribution of species comprising selected epipelagic genera of calanoid copepods. The results provide a relatively sharp view of speciation in each genus and the means to infer the modes of evolutionary history within each group. Studies of this nature are the basis for understanding the historical aspects of geographic dispersal, community organization, and pathways of ecological evolution in the pelagic environment.

The results to date clearly indicate several biogeographical generalizations: (1) warm-water species that breed regularly up to mid-latitudes tend to be circumglobal in distribution and probably maintain gene flow around South Africa; (2) warm-water species that breed regularly only in low-latitudes are provincial and may have one or more tropical cognates in other oceans. The tropical (equatorial) copepods tend to be restricted to either (a) the Atlantic Ocean, (b) the Indian Ocean and the western portion or more of the Pacific Ocean, or (c) the eastern tropical Pacific Ocean.

Taxonomic analyses have been refined by development and application of integumental organs as taxonomic characters. The arrangement, numbers, and morphological types of organs provide diagnostic features applicable to regional populations, species, species groups, the genus, and the family. The use of these newly developed characters and recognition of morphologically and geographically distinct populations among epipelagic copepods have led to the discovery of a number of new species formerly undistinguishable from previously described forms.

Biogeographic patterns in the coastal zone of the American continent and an evaluation of American species of *Labidocera* (Copepoda) were outlined. The results indicate strong selection pressures operating on secondary sexual structures but little or no evidence of selection for dividing food resources by morphological factors such as feeding appendages or body size. Also, the greater the extent of geographical overlap in any pair of species the more striking are the differences in their sexually modified structures.

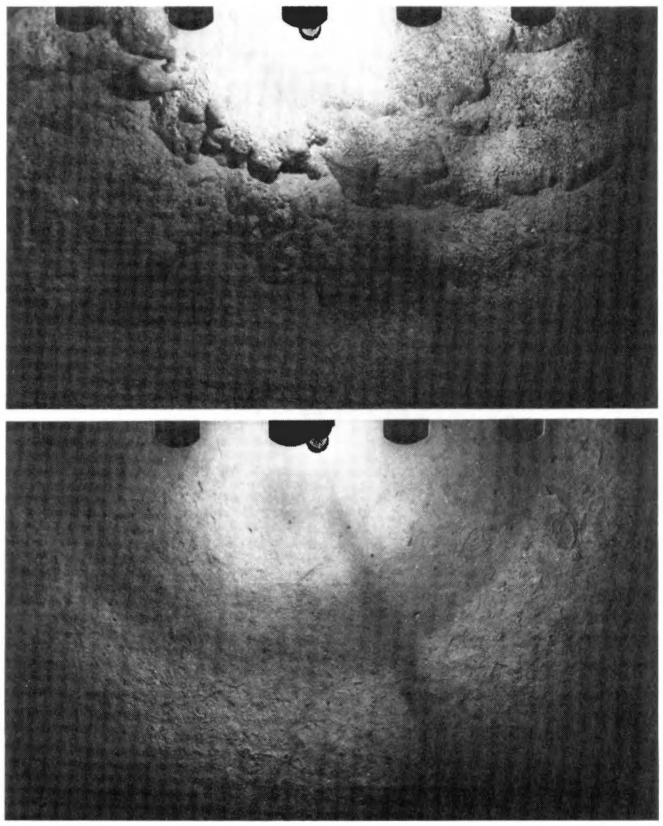
A study concerned with the utilization of copepods by non-copepod predators was also undertaken to determine whether copepods are preyed upon selectively. Evidence indicating that copepods are being selected on the basis of body size was obtained from analyses of the stomach contents of sergestid shrimps and young gadiform fishes.

Marine Physical Laboratory

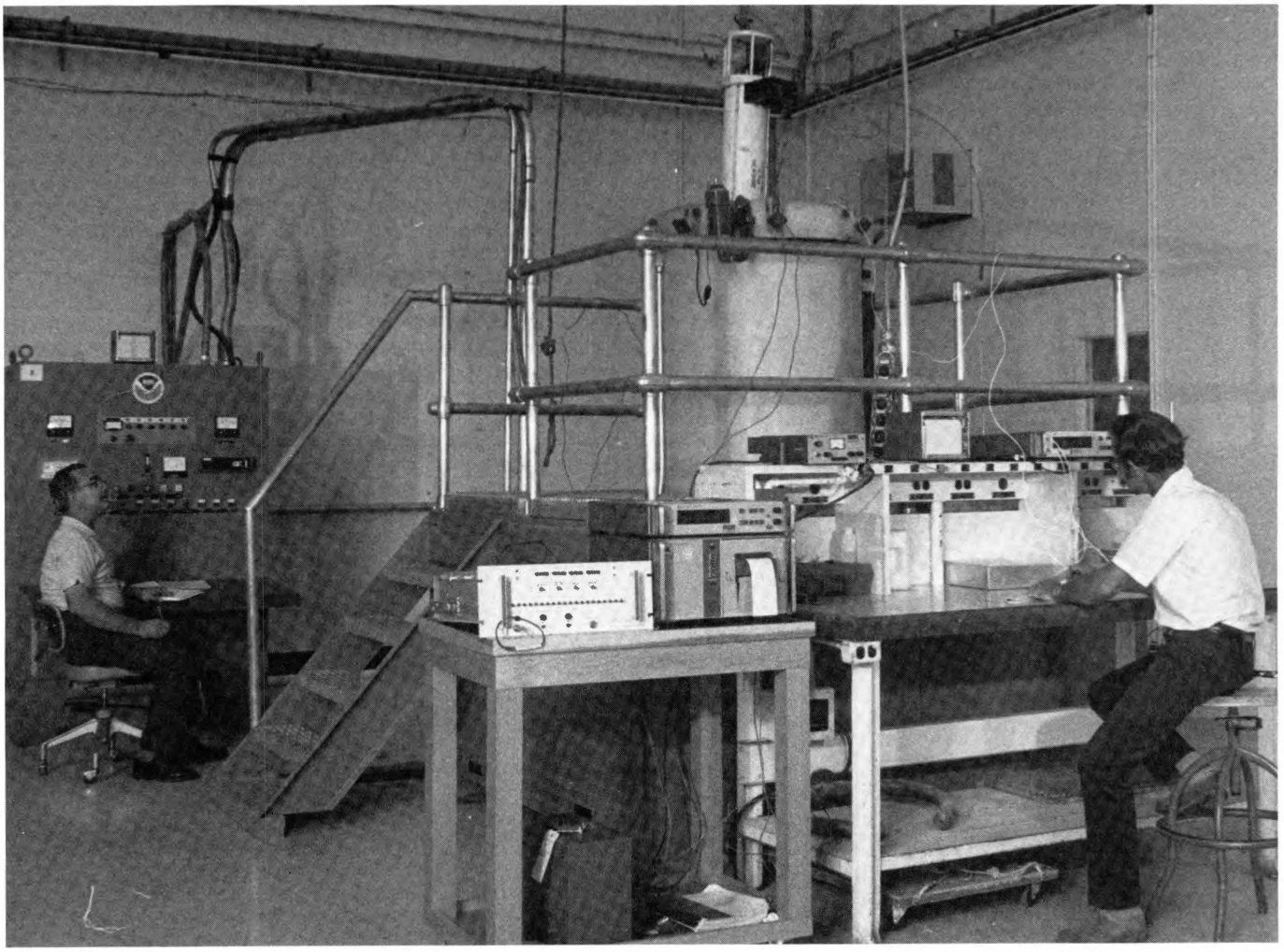
While a large portion of the Marine Physical Laboratory's (MPL) effort is devoted to ocean acoustics, work in other areas of marine science has expanded to include such diverse fields as geomagnetism, bottom topography, thermodynamics, physical chemistry, ocean engineering, and hydrodynamics. Contributions to these disciplines by members of the MPL staff are reported in some 50 publications issued by the Laboratory during the past year.

As a visting research associate under sponsorship of the Navy's Professional Development Program, Dr. Henry Cox completed theoretical investigations of the spatial correlation among acoustic sensors arbitrarily positioned in noise fields and the effects of mismatch on optimum array signal processors. In the former study, Dr. Cox developed explicit expressions for the second-order statistical relationships between the outputs of pairs of omnidirectional sensors positioned in a noise field described by an arbitrary directional density of uncorrelated plane waves. Applying the results to the problem of vertical directionality of ambient sea noise, he was able to develop models that are in agreement with a large body of measured data for the high-frequency and low-frequency vertical distribution of ambient noise sources.

In the second investigation, Dr. Cox demonstrated some rather severe effects of mismatch on the resolving power and signal response of optimum array processors. Having determined the exact conditions for resolution of closely spaced sources by an optimum beamformer, he applied the results to a line array and compared its resolution capability with that obtained using a conventional beamformer. For the optimum processor, it was found that an extremely large output signal-to-noise ratio is required to achieve a resolving power significantly better than that predicted by the classical limit.



The Marine Physical Laboratory's Deep-Tow instrument package provided these bottom photographs of scoured-rock outcrops and burrowed sediments in the Samoan Passage.
Marine Physical Laboratory



Calibration of a Salinity/Temperature/Depth instrument is under way at newly established Southwest Regional Calibration Center in San Diego.

Marine Physical Laboratory

SIC TRANSIT SONITUS is the title given to a concept developed by the late Dr. Frederick V. Hunt, wherein detection of a moving sound source is achieved through measurement of the variation in signal amplitude as the source moves past the monitoring sensor. Under the direction of Dr. Victor C. Anderson, a *SIC TRANSIT SONITUS* instrumentation system has been designed and implemented. In February of this year, a cable was laid between North Island and a point eight miles west of the tip of Point Loma, where the acoustic sensor was installed on the sea floor. The cable link under San Diego Bay to the unique signal processor located at MPL was completed in May. Current studies are devoted to confirmation of the extremely high detection sensitivity predicted for the system, and the relationship of this sensitivity to the false-alarm rate.

A project has been initiated by Drs. Anderson and Hugo F. Bezdek to observe the high-frequency sound scattering from fine-scale, layered structures of temperature and salinity gradients with a view toward determining the horizontal extent and temporal behavior of these structures. An array approximately 14m square, supporting 144 conical reflectors and their transducers, is being constructed. The cones and hydrophones, together with the essential signal processing apparatus, have been designed and are under construction. It is expected that the array will be completed and ready for sea in the coming year.

Dr. Bezdek has also been engaged in the determination of the pressure dependence of acoustic attenuation in the sea. Results of his measurements in deep water near San Diego indicate that the attenuation at 75 kHz is considerably more sensitive to pressure than has hitherto been believed. It appears that the pressure dependence is related to a shift in both the chemical compressibility and the relaxation frequency related to multistate dissociation reactions of $MgSO_4$. Other measurements demonstrated that volume reverberation is a negligible factor in the attenuation at this frequency.

Preliminary consideration of a large-aperture, passive, acoustic array was begun by a team under the direction of Dr. Anderson. Consisting of three major facets; namely, the array configuration, an advanced-technology, sound-absorbing baffle, and a high-resolution, signal-processing system, the large-aperture-array project has involved a number of design studies in each of these areas.

An array measuring approximately 6 X 18m was determined to be the smallest that could accommodate a reasonable number of full-size baffle elements. Several baffle materials were investigated and a flexibilized polyester was selected as being the most appropriate, since this material had satisfactory physical properties and was low in cost. Solutions to the several remaining design and construction problems are presently being purused. It is anticipated that the large-aperture array will yield a significant improvement in passive acoustic detection.

Under the supervision of Dr. Gerald B. Morris, efforts on equipment development for the Long-Range Acoustic Propagation Project resulted in the completion of a 48-element, analog, adaptive, beamformer unit. Initial at-sea testing of this unit in conjunction with an existing 20-hydrophone array demonstrated its satisfactory operation.

The beamformer operates over the 10 Hz to 1,000 Hz frequency band and can form up to 512 beams; however, only a maximum of 24, full-frequency, bandwidth beams can be digitally recorded or processed by companion equipment. Modifications have been introduced to permit recording of the full-beam sets for selected narrow-band frequencies. Work is under way to design and construct a minimum of two, 24-element arrays in order to exploit more completely the capabilities of this programmable beamformer system. Continued development and improvement of the 20-element, vertical, hydrophone array system has resulted in a variety of possible vertical spacings. The first of two basic configurations utilizes a distribution of hydrophones in groups at four widely spaced depths from the sea floor to within about 200m of the surface in the deep ocean. A second deployment configuration is the equally spaced, 20-element array that is to be employed in continuing studies of the beamformer until other proposed arrays are completed. During September and October, 1972, ambient sea-noise and signal propagation studies were conducted using the equally spaced array suspended from R/P FLIP, which was stationed in a three-point moor in the deep ocean west of San Diego.

An experimental study of the effects of body diffraction and enclosures on the frequency response and directional characteristics of hydrophones mounted in axisymmetric bodies containing resonant structures has been undertaken by Dr. Robert A. Rasmussen. Data obtained thus far reveal severe distortions in hydrophone frequency responses and directivity patterns even in the absence of an enclosure. The distortions are attributable to interference between incident and scattered waves and to radiation from the body at frequencies corresponding to parasitic oscillations excited by the incident wave. Presently under investigation are effects of a streamlined hydrophone enclosure and the possibility of canceling hydrophone responses to body vibrations by subtracting signals from internally mounted accelerometers.

The MPL-developed Oceanographic Research Buoy (ORB), in addition to serving as a surface support platform for MPL's Remote Underwater Manipulator (RUM), was used in support of a variety of U.S. Navy underwater acoustics experiments. Six operations, totaling 65 days at sea, were carried out in support of joint Naval Undersea Center (NUC)-MPL projects. In much of this work, the MPL Deep Acoustics Reverberation Studies System was suspended from ORB and used as a high-precision acoustic transmitter/receiver in the free-field calibration and evaluation of the experimental sonar and MPL's Digital Multibeam Steering (DIMUS) beamformer installed aboard the U.S. Navy research submarine *Dolphin*.

In a continuing work-performance study, the ORB/RUM Remotely Manned Sea-Floor Work System was used in three separate operations. ORB spent 24 days moored on station while RUM performed a variety of work tasks on the sea floor at depths ranging from 155 to 1,235m. Work included search, observation, and recovery of objects. A malfunctioning, bottom-mounted sensor array, weighing over 400 kg, was located, brought to the surface, repaired, and returned to the sea floor at 160m. RUM was used to install and recover acoustic navigation transponders. In another underwater acoustics experiment, the manipulator was used to place several sonar targets on the bottom for performance measurement of a high-resolution, narrow-beam sonar carried on the RUM vehicle. Soil-mechanics and trafficability studies were continued with emphasis on the measurement of sinkage and track slippage, and on cone-penetrometer, sediment-strength measurements and sediment sampling for laboratory analysis. A rock drill was designed, fabricated, and fitted to the RUM vehicle. This drill is designed to obtain documented, oriented cores approximately 4.5 cm in diameter and up to 3m in length.

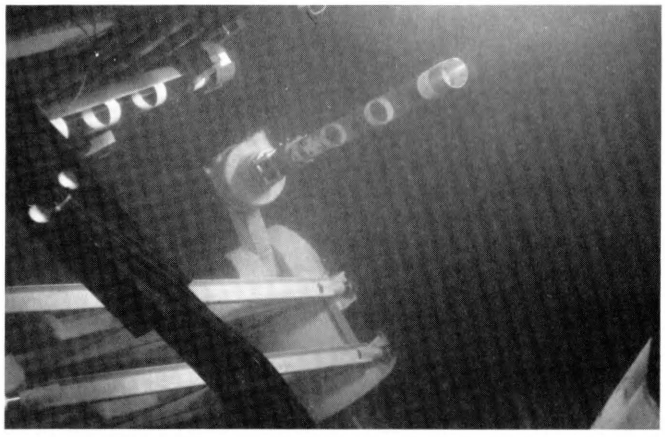
Studies by Drs. Frederick H. Fisher and Robert B. Williams of acoustic propagation fluctuations caused by bottom topography variations continue and will be aided by the development of a high-resolution, 90 kHz, scanning echo sounder, which is designed to measure bottmm slopes in two orthogonal directions. This scanner will be mounted at the 90-m depth level of FLIP, so results obtained on propagation work can be directly checked with the echo sounder as FLIP is towed over the site of the propagation runs. Preparations are being made for the MAI HAI II operation in the Hawaiian area, in which the effects of bottom topography, surface-duct thermal stability, and internal wave activity on acoustic propagation will be studied in several different areas.

In Dr. Fisher's work related to understanding the chemistry of sound absorption in the ocean caused by $MgSO_4$, measurements of electrical conductance in $MgSO_4$ solutions have been completed as a function of pressure, temperature, and dielectric constant. The analysis of the atmospheric pressure data has been completed using the latest theoretical conductance equations with the kind help of Dr. J. Justice of France. It appears, however, that the pressure data need to be analyzed with a simpler equation because of larger experimental errors. Pressure conductance work has also been initiated on the unsymmetrical electrolyte Na_2SO_4, for which conflicting predictions appear in the literature regarding its equilibrium constant at elevated pressures. Its pressure dependence is also involved with pressure dependence of sound absorption caused by $MgSO_4$ through ion pairing effects.

Temperature-jump work in conjunction with Dr. S. A. Levison of the Scripps Clinic and Research Foundation in La Jolla continues on the boric-acid relaxation; this is believed to cause the anomalous increase in sound absorption below 1 kHz. Measurements of Lake Superior water show the effect does not exist there, contrary to acoustic work previously reported for that water. Attempts to increase the relaxation frequency in seawater by adding boric acid were unsuccessful. This was an attempt to facilitate laboratory measurements of acoustic attenuation caused by boric acid.

Seismic refraction studies conducted by Drs. Russell W. Raitt, George G. Shor, and Roger N. Anderson were devoted to analysis and publication of the results of previous expeditions and preparation for the work on Tasaday Expedition, which is scheduled for the fall of 1973. Two papers delivered on the results of Iguana Expedition showed the presence of anisotropy of horizontal wave velocity of the upper mantle in the Cocos Plate between the East Pacific Rise and the Central American Trench. The maximum velocity is directed northeast-southwest, the presumed spreading direction, in agreement with previous anisotropy results in other oceanic areas.

Development and use of a two-wavelength, infrared, radiometer system to investigate the thermal interaction between the ocean and the atmosphere continued under the direction of Dr. Stephen Rearwin. The radiometer was operated on the NUC tower off San Diego during a six-week period and on two cruises of the FLIP. The purpose of these experiments was to obtain moderately long data records of radiometric temperatures, internal wave height, air temperature and dew point, wind speed and direction, net radiative heat flux, and bulk-water temperature, with the aim of understanding the complex interactions that occur in the marine boundary layers. Results of the tower experiments indicate that, under certain conditions, there is a direct interaction between internal waves and radiometrically observed, sea-surface temperature. Preparations are under way to use the radiometer system in a laboratory wind/water tunnel experiment to measure the effects of mechanically generated capillary waves on water surface temperature and total heat flux through an air/water interface under controlled conditions. It is expected that the experimental results will be compared with theoretical work done elsewhere.



RUM (Remote Underwater Manipulator) deploys coring device for sediment sampling at 1,300-m depth.

Marine Physical Laboratory

Dr. Leonard N. Liebermann has been conducting research in two unrelated areas: infrasonics and ferromagnetism. The term "infrasonic" refers to underwater sounds in the frequency range 1 Hz - 10 Hz, or below the limit of human hearing. These sounds have enormously long wave lengths, up to 1.6 km in length, which leads to new unsolved problems in underwater sound propagation. The problems become enhanced in shallow water, where dimensions of the acoustic wavelengths can be comparable to the water depth. New hydrophones have been developed for reception of the displacement component of infrasonic waves, with the objective of facilitating reception near the sea surface. A number of trials were conducted in near offshore waters with these new receptors.

Ferromagnetism is one of the oldest topics in physics, but it is not yet completely understood. Dr. Liebermann's research has uncovered a hitherto unknown phenomenon: the metals iron, nickel, and cobalt, when strongly magnetic, appear to be non-magnetic on the surface. The non-magnetic region, termed "dead layers," is only a few atomic layers thick and, hence, is difficult to observe in large samples, but becomes apparent in thin metallic films, when a specially developed magnetometer is used. Explanation of this phenomenon appears to be a quantum mechanical effect that is important to the basic understanding of magnetism.

For the past several years, Dr. Fred N. Spiess has been conducting an internal-wave observation program from the FLIP. Temperature is the fundamental quantity measured in this experiment. Time fluctuations in the depth of a given isothermal surface are ascribed to internal-wave vertical displacements. Profiles of temperature vs. depth are repeatedly taken at three horizontal locations surrounding FLIP, enabling a four-dimensional (three-space and time) view of the internal wave field. This year saw a significant enlargement of the sensor array. Heavy-duty electric winches were incorporated into the profiling system, thereby increasing the depth of the profiled water column to 450 m. Introduction of longer booms extended the horizontal dimensions of the array to 35 m. Computer software was developed which afforded *in situ* calculations of internal-wave spectral estimates.

Major cruises were conducted off the California coast during November, 1972, and June, 1973. In addition to providing a basic statistical description of the wave field, comparison of the observations from the two cruises will furnish some insight into the seasonal variability of internal waves. The second cruise was undertaken jointly with three other groups from SIO. Temperature microstructure measurements (Drs. Gregg and Cox), mid-water temperature field observations (Cairns, Williams, and Dr. Munk), and sea-surface radiometric data (Dr. Rearwin and Foster) were obtained in addition to the FLIP observations. An exceptionally complete characterization of upper-ocean temperature variability will result from this joint operation.

More than 200 new heat-flow measurements were made in the Pacific Ocean during the past year by Prof. Victor Vacquier and Dr. Roger N. Anderson. A high-amplitude, sinusoidal oscillation of heat-flow values on the crest of the Galápagos Spreading Center was observed and determined to be caused by massive hydrothermal circulation in the crestal environment of that mid-ocean ridge. High heat flow was found to be related to metallogenesis in the Bauer Deep, of the southeastern equatorial Pacific. This same oscillatory heat-flow pattern, combined with sampling of sediments and mapping of seismic reflectors in the Mariana Trough, of the western Pacific, further established the correlation between hydrothermal circulation in the oceanic crust and metalliferous sediment deposition. These three varied environments have in common the intrusion of a major heat source associated with sea-floor spreading. Heat flow thus may become an important exploratory tool for the discovery of new metalliferous deposits on the floor of the world's oceans.

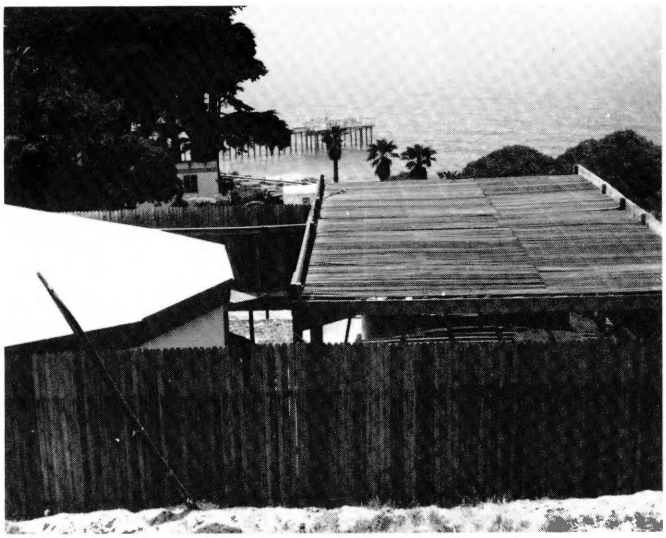
Heat-flow studies and related geophysical work in the central Gulf of California are being conducted by Lawrence A. Lawver. A primary goal of these investigations is the delineation of similarities between the Gulf and the Red Sea that might lead to the discovery of the type of metalliferous hot brines found in the latter. Three cruises to the Gulf were completed last year. Seven heat-flow measurements were made during a three-week cruise aboard University of Southern California's R/V *Velero IV,* while two cruises in Scripps's R/V *Oconostota* afforded 47 new measurements. Heat flow in the Guaymas Basin and the Farallon Basin averaged 180 mW/m^2 (4.3 Heat Flow Units) and 220 mW/m^2 (5.2 HFU) respectively, which is roughly three to four times normal. Two values in excess of 500 mW/m^2 were observed: the first in the southwest central Guaymas Deep, the most probable location of present spreading; and the second at approximately 10 km southeast of the Central Farallon Deep. The measurements obtained thus far have been of value in specifying regions of current tectonic activity.

Dr. Spiess served as chief scientist during sea-floor studies conducted at two locations in the South Pacific. These studies utilized the deep-tow instrument package developed at MPL.

Five small patches of the floor north of Samoa were examined. At each site an array of acoustic transponders was used for navigation, and current meters (19 stations) and cores (20) sampled bottom currents and sediments. The objective was to learn enough about the hydrography and geology in a range of high-energy abyssal environments to understand the relationship between the two in both erosional and depositional regimes. The five survey areas, listed from south to north, were: (1) at a depth of 4.8 km on the archipelagic apron 100 km north of Tutuila, where an area of hyperbolic echoes covering the surface of a thick wedge of acoustically transparent sediment overlying turbidities was resolved into a train of sedimentary ridges parallel to the contours and the measured bottom currents; (2) within the Samoan Passage (at 8° 30′S, 168° 45′W, 5.2 km depth) where lateral variations in the rapid (20 cm/sec) flow of Antarctic Bottom Water (AABW) into the Central Basin of the Pacific were measured and compared with sediment facies distribution; (3) at a major sill in the Passage (8° 18′S, 168° 30′W, 4.75 km maximum depth), where particular attention was paid to the vertical variation and upper boundary of the AABW, and to the geological effects of this variation; (4) at the northern exit of the Samoan Passage (7° 35′S, 168° 30′W, 5.6 km maximum depth), where the current speed diminishes and there is a transition from a scoured landscape covered with manganese nodules to a depositional terrain remarkable for the several varieties of regular wave forms developed in fine cohesive sediments, and (5) in the southern part of the North Tokelau Trough (7° 15′S, 168° 30′W, 5.8 km maximum depth), where the AABW current is temporarily accelerated by impinging on a 0.6-km high fault scarp, which has an erosional valley and a field of longitudinal erosional furrows at its foot.

A small area (10X16 km) on the northeast flank of the Line Islands apron was also studied in detail. A moat up to several kilometers wide and 30 m deep separates an east-west trending seamount at the southern edge of the area from the main sediment apron, which is over 0.5 km thick. Surface ship 3.5-kHz profiles show that the relief of this moat is a result of non-deposition of a surface sediment layer that thickens northward to 35 m. Much of this section shows large-scale cross-bedding that dips in a northerly direction; current-meter data indicated southwesterly flow during the survey. In marked contrast, in the northern portion of the area, a much more spectacular moat has been eroded 75 m below the smooth surface of the surrounding apron. This irregularly shaped feature is elongated in a north-south direction and is more than 7 km in length, although the adjacent sea peak (only 15 m high) is only 1 km in diameter. High-resolution reflection profiles show that many parallel, flat-lying horizons in the sedimentary apron are truncated at the walls of the moat, and bottom photographs show outcropping rock ledges that parallel the contours of the moat. Of the 4,000 bottom photographs available, current ripples were observed only on the floor of this moat; highly reflective material on the floor of the moat is suggestive of a lag deposit. This irregular depression apparently was eroded by normal bottom currents flowing around the small sea peak.

Under contract to the National Oceanographic Instrumentation Center of the National Oceanic Atmospheric Administration, the Southwest Regional Calibration Center was established at 9284 Balboa Avenue in San Diego. Maurice S. McGehee is manager of the Center, and Drs. Spiess and Fisher are guiding its development. It is anticipated that additonal facilities will be available not only for calibration of standard oceanographic instrumentation, but also for research purposes related to establishing oceanographic instrumentation measurement standards.



Overlooking the Pacific is Neurobiology Unit's facility for studying behavior of sharks and their orientation to magnetic fields weaker than those of the earth.

Neurobiology Unit

Neurobiology Unit

Drs. Theodore H. Bullock and Christopher J. Platt made the first study of the physiological responses in the brain of an elasmobranch to feeble electric signals in the water by recording nerve cell activity in the brain of *Torpedo*. This is the electric ray, known to antiquity for its powerful jolt. But the same exquisitely sensitive electroreceptors (ampullae of Lorenzini) and brain responses to weak, low-frequency, electric fields were found in other rays and common sharks. This work was largely done in the new International Brain Research Laboratory at the Marine Biological Station in Kotor, Yugoslavia.

Dr. Adrianus J. Kalmijn designed and supervised construction of a special facility for behavioral experiments on sharks, featuring fiberglass tanks 3 m and 6 m across with limited interference by electrical, magnetic, vibratory, and light stimuli. These tanks have permitted the demonstration with small sharks that the animal is sensitive not only to very small voltage gradients (reported previously: 0.01μv/cm) but also to local magnetic field distortions much weaker than the earth's.

Dr. Walter Heiligenberg developed the first quantitative test for the performance of electric fish in the active mode of detecting objects by their distortions of the fish's a.c. electric field. This test is an extension to the electroreceptor domain of the well-known optokinetic response to the visual stimulus of moving stripes, and may be called the electrokinetic response. Horizontal, small amplitude, sinusoidal motion of vertical strips cause the hovering electric fish to maintain its position between them by moving back and forth, providing the strips are electrically opaque plastic and not electrically transparent agar. Bode plots of gain and phase with frequency of oscillation permit estimation of the effect of strip width, distance, and jamming.

Dr. C. D. Hopkins and E. I. Knudsen found that the sensitivity in so-called "wave species," by single receptor discharge and by behavioral threshold, is sharply peaked at a "best" frequency which is tuned to the individual's electric organ output frequency.

Dr. Joseph Bastian found cells in the cerebellum in these fish which are sensitive to the slow motion of objects in the water near the fish, and analyzed their properties, including the simultaneous sensitivity to position of the tail (therefore, the orientation of the electric dipole field) or to visual objects. The resulting computer-displayed 3-D contour maps are the first exteroceptive receptive fields for cerebellar units.

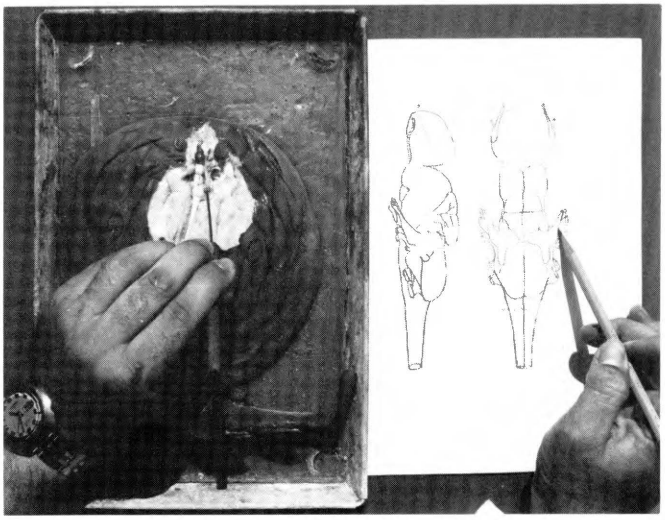
Drs. John Byrne, Harold Atwood, and Henning Scheich were visiting scientists who completed studies here on the neurobiology of fish and crustaceans.

Drs. David Lange and Peter Hartline, studying the neurophysiology of vision in cephalopods, substantially completed the linear systems analysis of squid and octopus electro-retinograms, showing a rather simple low-pass characteristic. Squid optic nerve responses yielded many complicated responses that are rather surprising from an eye which seems to be anatomically simple. The ability of the octopus to discriminate between flashing and steady lights was established by Stanley St. John and graduate student Robert Springer. The importance of vision in squid schooling was established by Dr. A. C. Hurley, and quantitative studies were initiated that promise to reveal information on both schooling and vision.

Previous work on temperature-dependent bursting in the optic nerve of *Limulus* was extended to intracellular recording. The mechanism is clearly not that spikes are selectively blocked but rather that the intrinsic pacemaker properties of the cell are altered (Krausz, Dodge, and Lange).

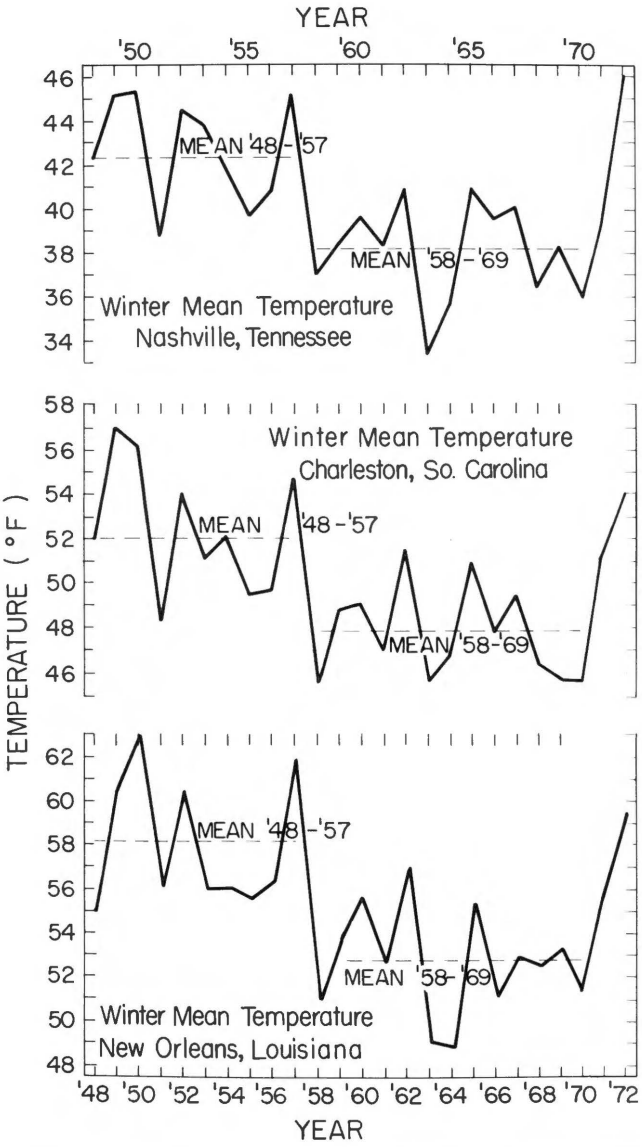
Preliminary work was done on the relationships between vision and the infra-red detection system in rattlesnakes. Units in the IR system recorded in the "optic" tectum showed a remarkable amount of neural image formation from an essentially imageless receptor organ (Hartline).

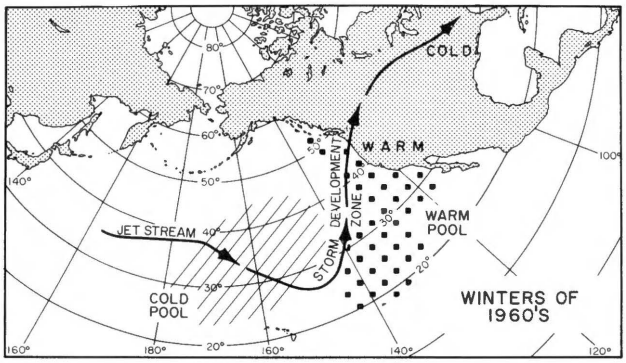
Mathematical work in the area of theoretical ecology using standard matrix techniques achieved a simplified formulation of John D. Isaacs' unstructured marine food web. Use of a 3X3 interaction matrix allowed for generalization of his model to achieve more realism (Hurley and Lange).

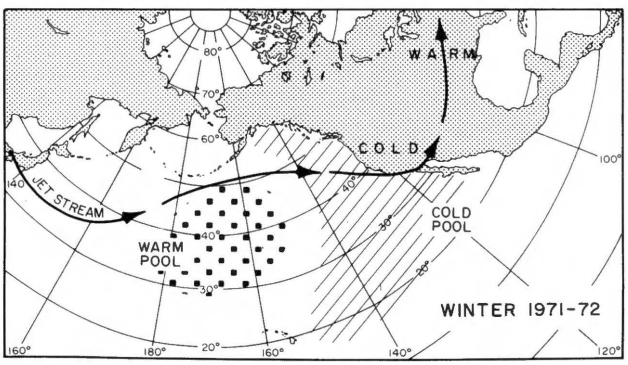


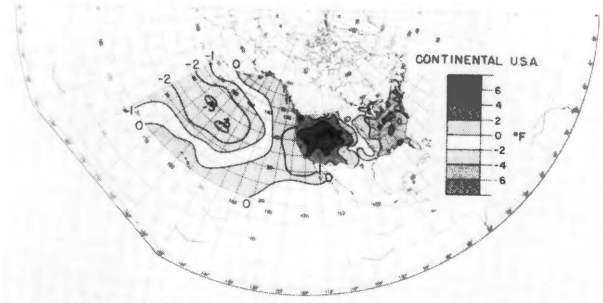
Scientist in Neurobiology Unit uses instrument to point out in an electric ray (Torpedo) *the nerve carrying electrical input to brain from electro-sensitive receptors in ray's skin that detect feeble, low-frequency currents in the sea, such as those given off by prey fish. Drawing shows location of same nerve scientist is studying.*

Neurobiology Unit

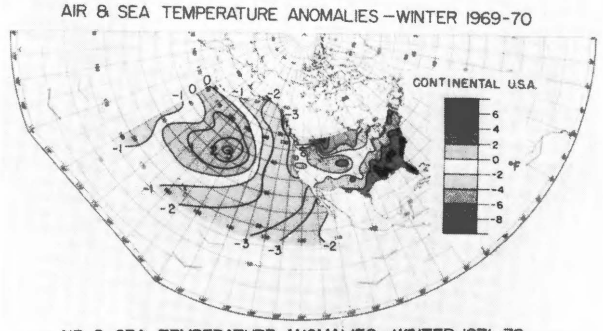








AIR & SEA TEMPERATURE ANOMALIES—WINTER 1969-70



AIR & SEA TEMPERATURE ANOMALIES—WINTER 1971-72

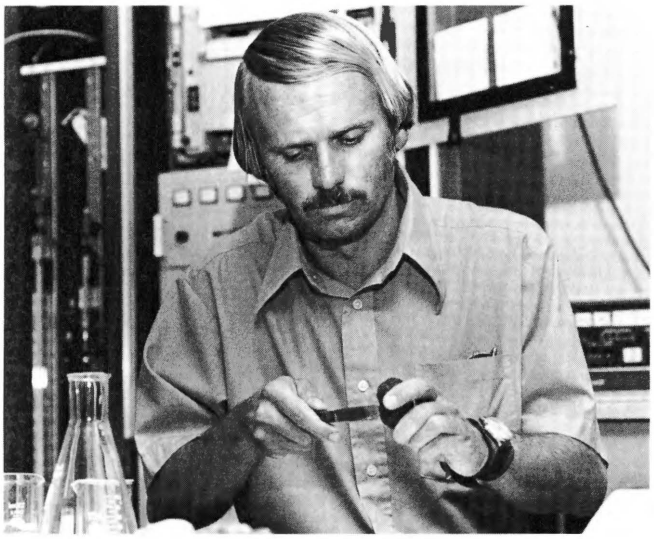
NORPAX

> . . . The moisture and varying temperature of the land depend largely upon the positions of the(se) currents in the ocean, and it is thought that when we know the laws of the latter we will, with the aid of meteorology, be able to say to the farmers hundreds of miles distant from the sea, "You will have an abnormal amount of rain during next summer," or "The winter will be cold and clear," and by these predictions they can plant a crop to suit the circumstances or provide an unusual amount of food for their stock . . . From a study of these great forces, then, we derive our greatest benefits and any amount of well-directed effort to gain a complete mastery of their laws will revert directly to the good of the human race.
>
> Lt. John E. Pillsbury, 1891

This appealing prescription has gained increasing importance in recent years with the recognition that the surface layers of the ocean have a profound influence on climate, and that there are strong indications that abnormal weather exists both in the atmosphere and the ocean. The NORPAX (North Pacific Experiment) Program, supported jointly by the National Science Foundation and the Office of Naval Research, has taken as its task the understanding of the slowly changing 'weather' in the upper layer of the ocean and its relation to the overlying atmosphere. Principal Scripps participants in NORPAX are Drs. Tim Barnett, Robert L. Bernstein, Charles S. Cox, Russ E. Davis, Carl A. Friehe, Myrl C. Hendershott, Joseph Huang, Kern F. Kenyon, Robert A. Knox, Walter H. Munk, Jerome Namias, Robert H. Stewart, Richard T. Wert, and Warren B. White, and Joseph L. Reid.

The problem NORPAX has taken up is a large one and the approach to it has been divided into several pieces.

Statistical effort has been directed toward describing climatic changes in time scales of months to years, as derived from existing historical data. Dr. Namias has found convincing evidence of the relationship between atmospheric weather patterns overlying the Pacific Ocean and North America to the large-scale structures of sea surface temperature in the North Pacific. He is attempting to delineate how the sea surface temperature changes with time in response to the atmospheric driving forces and ocean motions. There is some evidence of abrupt shifts of climatic regimes that occur both in the ocean and atmosphere; this resulted in an appreciable difference in the conditions over the United States between the years 1948 to 1957 and from 1958 to 1969 (see illustrations). The warmer conditions in the east seem to have reasserted themselves in the 1970s.



Dr. Jeffrey Bada prepares shark vertebra for age-dating by a Bada-developed processed called racemization of amino acids. Vertebra was embedded in manganese nodule recovered from Horizon Guyot, in Pacific, during the Seven-Tow Expedition.

Drs. Bernstein and White, working on subsurface temperature measurements in the trade wind region northeast of Hawaii, discovered evidence of large baroclinic "eddies" that are 100 km in size. These are major features. The volume transport of a single, typical eddy is often comparable to or larger than the volume transport of such major features as the North Pacific Drift Current. These medium-scale eddies seem to be found throughout the ocean basins; their discovery in the Pacific followed earlier discoveries in the subtropical Atlantic.

During the 1972-73 fiscal year, NORPAX scientific, technical, and administrative staff were being assembled for the NORPAX program, under the guidance of the NORPAX Steering Committee. Planning began for the program's initial field experiment, POLE, scheduled to be carried out in the North Pacific early in 1974 under the general direction of Dr. Davis.

Ocean Research Division

A wide spectrum of studies in marine chemistry, geochemistry, ecology, marine geophysics, and physical oceanography is conducted by the research staff of the Ocean Research Division.

Several projects related to the ecology of kelp communities were carried out by Dr. Paul K. Dayton. These included a baseline study of natural population fluxes in Southern California kelp beds off Catalina Island, Del Mar, and Pt. Loma, and an intensive long-term study to quantify the mortality patterns caused by drifting plants at Pt. Loma. A series of experiments designed to evaluate hierarchies of competition for light between different algal canopies and to test effects of various herbivores and carnivores is under way. Comparative experimental studies of kelp beds in Chile, Argentina, and Alaska have been completed.

A series of research projects designed to evaluate the variation in natural populations in a number of nearshore habitats, including rocky intertidal and subtidal habitats in the La Jolla-San Diego Underwater Preserve, Bird Rock, and sand-bottom communities is under way; these studies were first started in 1957 by Dr. E. W. Fager and Arthur O. Flechsig.

Other research projects included predator-prey interactions in the sand-bottom area, population dynamics of the flora and fauna in intertidal and subtidal areas, and the ecological implications of the local invasion of *Sargassum muticum*, a Japanese seaweed.

Dr. Jeffrey L. Bada has worked with the racemization of amino acids. The racemization reaction involving aspartic acid received the most attention. This amino acid has one of the fastest racemization rates of any of the stable amino acids. At 20°C, the half-life is about 15,000 years. Thus, in the time interval datable by radiocarbon, a substantial amount of racemization of aspartic acid takes place. By determining the extent of racemization of aspartic acid in a bone that has been dated by radiocarbon, it is possible to calculate the effective, first-order rate constant for racemization *in situ*. Once this 'calibration' has been carried out, the reaction can be used to date other bones from the deposit, provided the temperature history of the deposit is uniform. Ages deduced by this method are in good agreement with radiocarbon ages. These results have provided evidence that the aspartic acid racemization reaction is an important chronological tool for dating fossil bones that are either too old or too small for radiocarbon dating.

On the other hand, if the age of biological materials is known, the amino acid racemization reaction can be used to calculate paleotemperatures in continental areas. This provides a useful paleothermometer over the last 30,000 years. These calculations have shown that average annual temperatures along the western Mediterranean coast were 4°C lower during the last glacial period, while in East Africa temperatures were 5-6°C lower. Thus, amino acid racemization has provided a new and powerful tool for studying conditions that prevailed in continental regions during glacial epochs.

Dr. James T. Enright has continued his research on 'biological clocks' in an intertidal isopod (*Excirolana chiltoni*). A major part of this program has involved experiments designed to understand the synchronization and rephasing of the endogenous rhythmicity, using mechanical stimuli comparable with those from wave-action on the beach. A second line of research has been an investigation of the synergism, in the effects of heavy water (D_2O) and cool temperature, on the free-running period of the rhythm. He was also deeply involved in the evaluation of the ecological consequences of using marine waters to cool coastal power generating plants; he demonstrated that the existing nuclear plant at San Onofre, California, has produced massive changes in abundance of the plankton (particularly *Acartia* spp.) in the nearshore environment surrounding the plant.

Dr. Charles Barry completed his field and laboratory study, under Dr. Enright's supervision, on habitat recognition and selection by a salt-marsh shrimp (*Hippolyte californiensis*). Robert Hartwick continued his research on celestial orientation of 'beach hoppers' (*Orehestoidea* spp.), which use the sun as a compass to find their way back to their habitat. Hartwick has now demonstrated that the searchlights on the Scripps Pier have had a major effect on the sun orientation of the local population of amphipods. The 'light pollution' has destroyed the effectiveness of their sun-compass response, which now leads them astray.

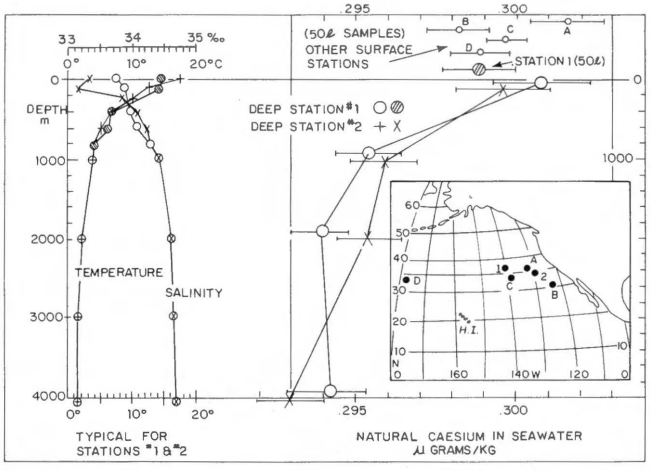
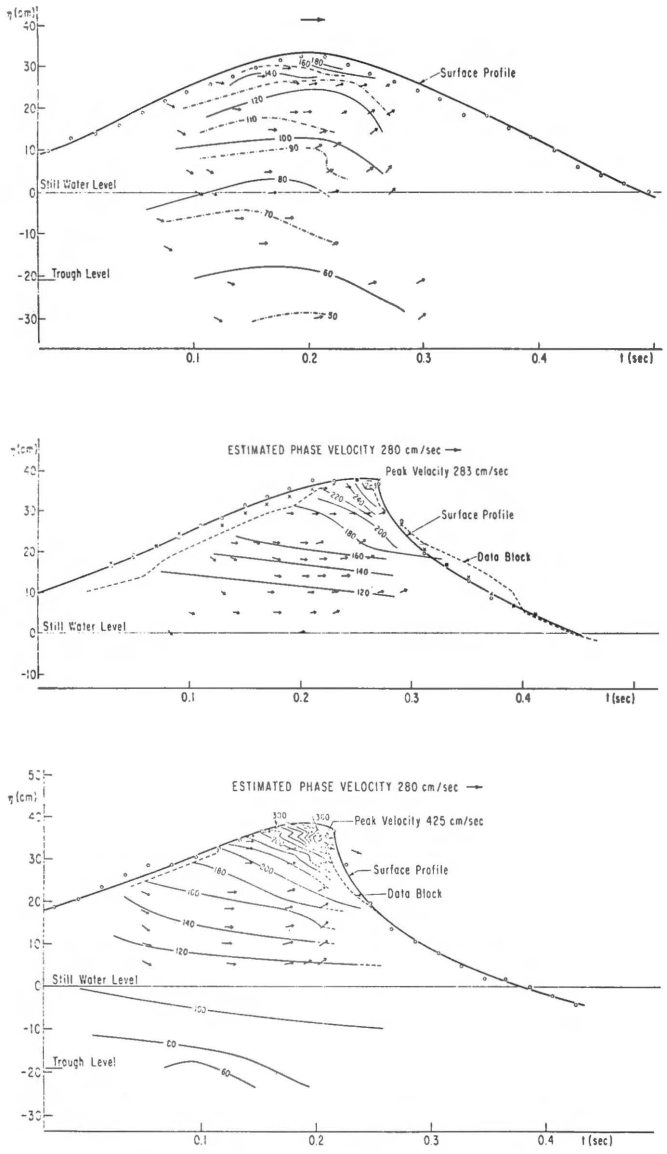


Chart shows concentration of natural cesium (normalized to 35.00 parts per thousand salinity) observed in surface- and deep-water samples in the North Pacific in 1973 by using newly completed special analytical equipment at Mt. Soledad Laboratory.

Mt. Soledad Laboratory



Figures from top to bottom show (1) flow direction (arrows) and velocity isolines (cm/sec) for 0.66 Hz wave 2.85 sec (1.9 wavelength) before breaking, with circles indicating surface profile data. (2) Flow direction (arrows) and velocity isolines (cm/sec) for 0.66 Hz wave at breaking point. Note that particle velocities at crest just exceed Stokes's limiting phase velocity. Circles and crosses indicate surface profile data. (3) Flow direction (arrows) and velocity isolines (cm/sec) for 0.66 Hz wave 0.3 sec (0.18 wavelength) after breaking. Research is that of Dr. William Van Dorn.

Ocean Research Division

Dr. D. John Faulkner concentrated his efforts on elucidating the functions and possible uses of marine natural products, while at the same time discovering new chemical structures. His studies on the chemical defense mechanisms of the sea hare (*Aplysia californica*) led to the discovery that the sea hare stores in the digestive gland the more 'toxic' chemicals that it encounters in its algal diet.

An investigation of the effects of insect growth regulators (shortly to be licensed for use) on selected crustaceans has shown that these potential insecticides can interfere with metamorphosis. One of these compounds, ZR-512, causes barnacles to metamorphose into adults without first settling on a surface. This precocious metamorphosis results in the death of the barnacle, since it must be attached to a surface in order to feed. This research illustrates how organisms might be controlled by treatment with 'pseudohormones'.

Research in the laboratory of Dr. William Fenical has led to a method of classifying algae according to their secondary metabolites. Although chemical taxonomy has been suggested many times in the past, this the first successful application of chemical methods at the species level.

Dr. Theodore R. Folsom continued studies at the Mt. Soledad Laboratory of radioactive fallout and traces of natural elements that behave similarly in the ocean. This year a computer-controlled flame emission spectrometer specialized for accurate measurement of small traces of cesium, rubidium, and lithium in the ocean was completed, and with it the extreme uniformity (relative to salinity) of cesium was demonstrated. Analytical precision near +-½% is required even though natural cesium is less than 0.3 ppb in the ocean. This precision was attained by advanced optical, mechanical, and electronic specializations. The distribution of natural cesium in the ocean is of importance to studies of the ultimate disposal of certain radioactive wastes.

Dr. Vernon F. Hodge, in collaboration with Dr. Folsom, also investigated radioactive traces in the marine environment, with special attention to the behavior of plutonium, a hazardous fuel nuclide, and to the comparative behavior of polonium, a natural radioactive material that also gives off energetic alpha particles. So far it has been discovered that natural and artificial alpha emitters deposit intensely on plant surfaces. Natural polonium accumulates to fantastic levels in certain tissues of higher organisms, but man-made radioactive plutonium is not accumulated. This is an encouraging prediction that in the future plutonium fuel will have some difficulty reaching human beings through sea food.

The Mt. Soledad Laboratory also studied the long-term biological availability and distribution of several radioactive elements that enter the oceans as atmospheric fallout or as nuclear power reactor wastes. Radioactivity found in the livers of albacore, caught off San Diego during the last ten years, suggests that cobalt, silver, cesium, and plutonium introduced into surface waters of the North Pacific will remain available to this tuna for a decade or more. To accelerate the radiochemical survey of plutonium, the alpha spectrometer systems at the Mt. Soledad Laboratory were greatly expanded last year so that as many as 13 samples can be counted at one time, something not generally available to chemists and biologists elsewhere.

Dr. Tsaihwa J. Chow, in a joint project with Dr. Edward D. Goldberg, determined the lead pollution records in Southern California coastal sediments by analyzing sediments from the San Pedro, Santa Monica, Santa Barbara, and Soledad Basins. An additional core was taken from the Los Angeles County sewage outfall at White Point to provide sediments containing domestic and industrial wastes. The ages of the sedimentary levels were determined by PB^{210} and Th^{228}/Th^{232} radiometry; the lead concentrations and isotopic composition were determined by mass spectrometry. The isotopic composition of the lead in these sediments is indicative of their sources. The Soledad Basin deposits contain lead with isotopic compositions similar to those of the weathering products from Baja California. The White Point deposits contain lead with isotopic ratios comparable to those found in gasoline sold in Southern California. The extremely high lead concentrations (averaging 400 ppm) in the sediments off the White Point outfall reflect the input of industrial and domestic wastes. Evidence indicates that the deposition most probably took place within the past few years or that it was caused by slumping.

The isotopic compositions of lead in the surface sediments of Southern California coastal basins are distinctly less radiogenic than those in the deep sections of cores that represent the prepollution drainage. The rates of lead accumulation began to increase in the basins off the Los Angeles coast in the 1940s.

The CO_2 Group, led by Dr. Charles D. Keeling, continued an investigation of the geochemistry of carbon dioxide with emphasis on air-sea interaction processes. An investigation of periodicities in atmospheric CO_2 concentration by Dr. Robert Bacastow has revealed an unexpected correlation of barometric pressure anomalies near the Equator with anomalies in the CO_2 trend at the South Pole. In 15 years of record, CO_2 has shown unusually high rates of increase four times; each occurrence was approximately one year after a period of abnormally low barometric pressure difference between Pt. Darwin, Australia, and Easter Island. This pressure difference is a well-known indicator of the so-called Southern Oscillation, a fluctuation in the

strength of the zonal winds with a period of about 2 1/2 years. Low pressure difference corresponds to weak zonal circulation. It is speculated that either less CO_2 is removed from the atmosphere by the southern oceans during periods of weaker winds, or that meridional transport from the industrial sources in the Northern Hemisphere is increased. Dr. Keeling and his associates, in cooperation with the New Zealand Institute of Nuclear Sciences, have been measuring atmospheric CO_2 near 40°S on the New Zealand Coast and are presently establishing a sampling station at Christmas Island on the Equator in order to improve Southern Hemisphere coverage with the view of better locating oceanic sources and sinks of CO_2.

In further work, this group has nearly completed a four-year recalibration of atmospheric standard gases used by laboratories throughout the world, and has continued to monitor atmospheric CO_2 in Hawaii, on a weather ship at 50°N, and at Scripps Pier. This latter program, in continuous operation since October, 1972, has produced a record of the influences of regional combustion on local air masses. The record indicates that when the air at Scripps is coming in from the sea, it is influenced over 90 percent of the time by man-made combustion, mostly from the Los Angeles area. Higher CO_2 levels are closely related to increasingly noticeable "smog" episodes. Comparison with similar data obtained from 1959 to 1961 indicates a doubling of air pollution levels that is probably caused by urban growth.

In Dr. Joris Gieskes' laboratory the main emphasis has been on the detailed study of the chemical composition of interstitial waters of deep-sea sediments. Intensive studies have been carried out on interstitial water samples in the northwest Indian Ocean and the Antarctic Ocean.

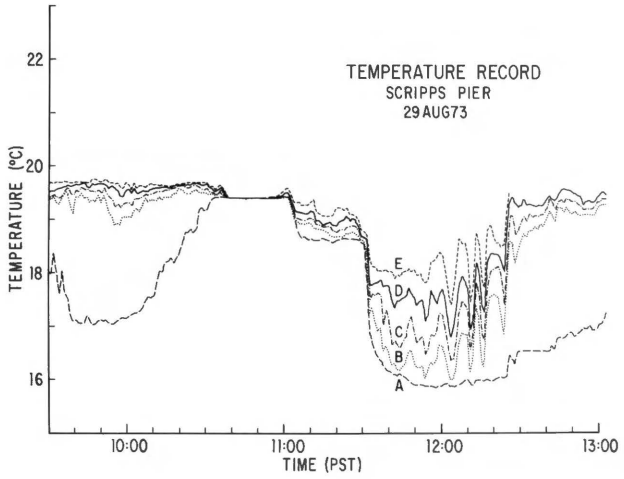
Dr. Theodore Warner, a visiting scientist from the Naval Research Laboratory, Washington D.C., studied the chemical composition of basal manganiferous sediments recovered by the Deep Sea Drilling Project. These studies, in conjunction with mineralogical studies by Dr. Miriam Kastner, and interstitial water studies, have led to a better understanding of diagenetic processes taking place in deep-sea sediments.

Further studies were carried out on the thermodynamics of mixed electrolyte solutions. Emphasis was given to studies of free-energy relationships, with particular attention to additivity relationships in mixed electrolyte solutions. This work forms a baseline study in the investigations of ionic interactions in electrolyte solutions.

Studies of convective processes were continued by Dr. Theodore D. Foster. Laboratory experiments on the cabbeling instability, induced by the mixing of two parcels of a fluid that has a nonlinear equation of state, were carried out. The cabbeling instability may play an important role in oceanic mixing, especially at low temperatures where the equation of state of sea water is more nonlinear than at higher temperatures. A heuristic theory of a hierarchy of convection was developed that predicted scales of convection cells ranging in size from a few millimeters to that on the order of the depth of the mixed layer. Laboratory experiments of two-dimensional convection in a Hele-Shaw cell showed that a secondary convection pattern of larger cells does develop from the initial smaller cells; however, the mechanism of interaction between the two scales of cells in the Hele-Shaw cell may be quite different than that which takes place in the ocean.

As part of MODE, the horizontal electric field on the sea floor of the Sargasso Sea was recorded at three stations for a period of three months. The first month's results are shown in an accompanying figure, together with three components of the magnetic variation recorded on Bermuda. (Data recorded by Dr. Ian Gough, University of Alberta, Edmonton, Canada.) The electric fluctuations can be visually decomposed into a high-frequency part (greater than 1/2 cpd), and a low-frequency part represented by the slow wobbling of the traces. Electromagnetically disturbed times, easily identified on the magnetic record, are seen to be highly coherent on all traces, for example, April 1-2 and after April 11. During the quiet time of April 3-11 the signature of the ocean tide and the 'solar daily variation' induced from the ionosphere are evident.

In contrast to the high frequency signals, the low frequency part (less than 0.1 cpd) is clearly somewhat variable across the array of sea-floor stations. This indicates that the barotropic ocean currents have a scale size comparable to the separation (100 km) between stations.



A 3½-hour temperature record from Scripps Pier, measured by Shore Processes Study Group, shows abrupt thermal fluctuation followed by train of internal waves. A-to-E are individual thermistors ranging in height from 1.2 to 3.0 m above bottom. Propagation of these periodic thermal fluctuations over continental shelf could be responsible for dissipation of significant amounts of energy in nearshore waters.

Shore Processes Study Group

The instrumentation used in this experiment is novel. It uses the stabilization properties of signal chopping to reject electrode drift by including the electrodes within the stabilized hoop, the chopping occurring within the water path. The sampling span was thus reduced from several kilometers to six meters, allowing recording of both horizontal components at once.

During the past several years, instruments capable of sensing centimeter and millimeter scale temperature and salinity fluctuations in the ocean have been developed under the leadership of Dr. Cox. Observations of variability on this scale are essential to an understanding of the mixing processes in the ocean. Dr. Michael C. Gregg, who developed a microscale conductivity probe while he was a graduate student of Dr. Cox, has led three major cruise legs to various locations in the Pacific to observe the distribution of microstructure activity. Dr. Cox led a cruise which took observations off the coast of South America and in the Drake Passage. Part of the microstructure research conducted by Drs. Cox and Gregg was supported by the Advanced Ocean Engineering Laboratory.

Late in 1972 the North Pacific Study in the Marine Life Research Group, directed by Professor John D. Isaacs, was reorganized under collaborative sponsorship of the Office of Naval Research and the National Science Foundation (Office of the International Decade of Ocean Exploration). It was renamed the North Pacific Experiment (NORPAX) *(Q. V.)*, and transferred to Scripps's Ocean Research Division under the direction of Dr. Cox.

The Shore Processes Study Group, under Dr. Douglas L. Inman, is engaged in studying and teaching the physical aspects of the nearshore environment. This group includes about ten graduate students and a professional staff of more than 20 who are employed in the Shore Processes Laboratory and the Hydraulics Laboratory. The new Shore Processes Laboratory, adjacent to the beach near Scripps Pier, was dedicated on March 24, 1973, as a Sea Grant Program Coastal Zone Laboratory.

Research objectives of the Shore Processes Study Group include (1) field and laboratory measurements of waves, winds, currents, and sediment transport; (2) identification and understanding of physical processes operative in the nearshore environment; (3) application of the understanding of these processes to the dispersion of pollutants and development of improved coastal engineering techniques, and (4) formulation of criteria for coastal zone planning. These research objectives are largely attained by the use of a sophisticated instrumentation system that was developed by Robert Lowe, senior development engineer, for obtaining data from nearshore waters.

Shore Processes Study Group team conducts field test of 20-m-long fluidizing pipe at Oceanside Harbor. Vertical pipe supports protruding through sand maintain fluidizing pipe at a fixed depth while it transports sand. Trench was excavated by fluidizer in 20 minutes after saturation of sand with water.
Shore Processes Study Group

The Shelf-and-Shore (SAS) simultaneous data system consists of several shelf stations deployed offshore for measuring data, and a shore station for receiving and recording data. The shore station is housed at the Shore Processes Laboratory and a series of shelf stations is deployed off La Jolla.

A shelf station has been installed three kilometers north of Scripps off Torrey Pines Beach for the past two years to make measurements of waves incident to the beach. Wave data have been measured from this station four times daily for the past two years in order to determine the directional spectrum of the wave field, and to compile a wave climate for the site. Dr. Inman and graduate students Steve Pawka and Linda Holmes have been analyzing these data, and are preparing a final report.

At the same Torrey Pines Beach site, three rangelines were established, and beach profiles have been surveyed at monthly intervals for two years in order to measure the seasonal changes in sand level. Charles Nordstrom is compiling the results of this study, and comparison of the profiles indicates that sand is rapidly transported offshore when high storm waves are coincident with high tides in winter, and the beach is gradually built up during the low-wave conditions of the summer.

Dr. Foster, in collaboration with Dr. Eddy C. Carmack, also carried out an extensive physical oceanographic investigation of the eastern and southern Weddell Sea. Preliminary evaluation of the data has shown that Antarctic Bottom Water probably forms by a three-stage process in which (1) cold, fresh, surface waters mix vertically with warmer and saltier intermediate waters, probably by means of the cabbeling instability, (2) this modified water mass intrudes onto the shelf region of the Weddell Sea west of about 30 to 40°W and mixes with the cold, salty water on the shelf to form a very cold type of bottom water which flows around the western Weddell Sea in a contour current near the base of the continental slope, and (3) this intense bottom water is diluted by the overlying intermediate water to form the classically defined Antarctic Bottom Water. Bottom-mounted, current-meter data were used to provide reference velocities for geostrophic calculations, and it was estimated that about 4×10^6 m^3/sec of Antarctic Bottom Water is flowing out of the Weddell Sea. Data from along the front of the Filchner Ice Shelf indicated that the ice shelf is melting and cooling the surrounding waters.

Dr. Robert A. Knox continued a project, begun when he was at the Massachusetts Institute of Technology, of conducting frequently repeated temperature and velocity profiles on the Indian Ocean Equator. The objective is to obtain information on the low-frequency (weeks-to-seasons) variability of equatorial currents in this unique ocean over which the wind stress changes so dramatically every year. Data collected thus far reveal the set up and destruction of the Equatorial Undercurrent in the spring of 1973, the sudden appearance of a surface eastward-flowing jet at the change of the monsoons, and a vareity of lesser fluctuations. The profiles are obtained in the field by British personnel stationed at the Royal Air Force base on Gan in the Maldive Islands.

Dr. Knox has also been analyzing deep hydrographic data obtained off the coast of Brazil in 1972, with the collaboration of A. F. Amos of Lamont-Doherty Geological Observatory. These stations were intended to resolve details of the northward flowing Antarctic Bottom Water and to examine the structure of this current in relation to the bottom topography over which it flows.

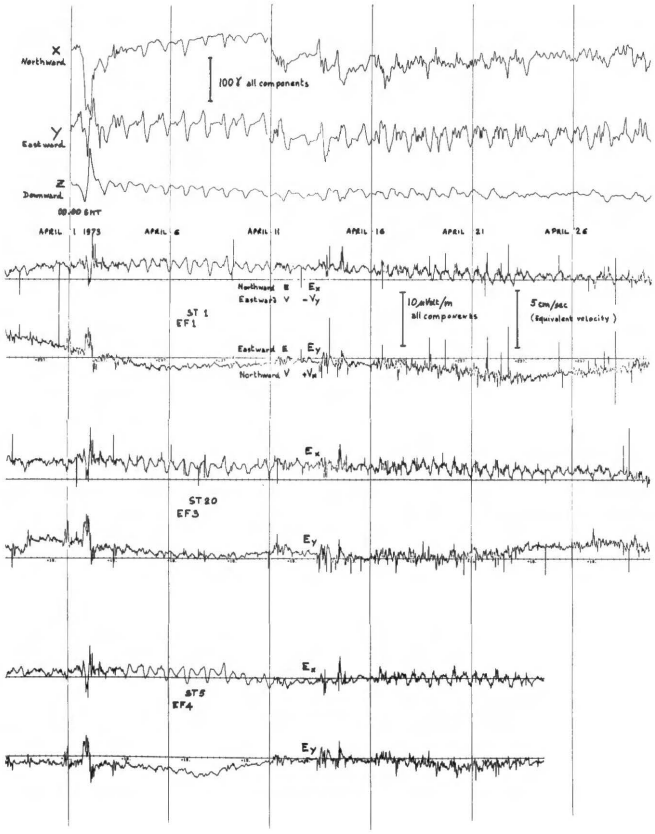
During the past year Dr. William G. Van Dorn continued his two-year laboratory study of the dynamics of periodic waves breaking in deep water under controlled reproducible conditions. This was a preliminary study to field experiments projected for 1975, in which he hopes to determine the statistical incidence of wave breaking in the open sea under storm conditions, and to compare their properties with those of the laboratory waves. Dr. Van Dorn's study was administered by the Advanced Ocean Engineering Laboratory.

The present experiments, conducted in the 2x2x43-m wave channel in the Institution's Hydraulics Laboratory, induced steep, computer-generated wave trains to break by two different methods; (1) by squeezing them laterally to the breaking point, and (2) by generating bi-harmonic series in a non-convergent section, so that subcritical waves overtake one another and break by supercritical reinforcement.

Representative results from the convergent breaking experiments are shown in the accompanying Figures 1-3, which compare the profiles and distribution of internal velocities as a particular wave approaches breaking, breaks, and plunges, respectively. It is apparent that wave growth and breaking is associated with increasing profile asymmetry and tilting of isolines of constant velocity so as to wrap around a high-velocity jet that develops on the forward crest face at the instant of breaking. Each of these plots required about two dozen reproducible wave series, generating a grid of some 800 data points and taking about an hour of computer time. Even so, the internal structure of breaking waves has never before been examined in like detail, most of which has yet to be explained theoretically.

The research activities of Drs. Carl Gibson, Carl Friehe, Francis H. Champagne, and Thomas K. Deaton, managed by the Advanced Ocean Engineering Laboratory, were concerned with the roles of turbulence in the oceans and atmosphere. Many of the physical processes, such as air-sea interaction, are dominated by turbulent, rather than laminar, motion. Most of their efforts were directed toward measurement of the turbulent velocity and scalar (temperature and humidity in the atmosphere, and temperature and conductivity in the ocean) fields in the upper portion of the ocean and the surface boundary layer of the atmosphere. From these measurements, knowledge of the turbulent transfer mechanisms of momentum, heat, water vapor,

Newly developed computer-controlled flame spectrometer specialized for determining extremely small traces of alkalies in seawater at Mt. Soledad Laboratory. Multiple samples and standards are compared repeatedly under control and evaluation of digital system.



Graph indicates, in three upper traces, three components of magnetic variations for month of April, 1973, on Bermuda. Below are horizontal electric field components at the sea floor for the same period. E_x is to the geographic north, E_y to the east. The low-frequency part of the electric field can be interpreted as the result of barotropic water current at right angles to the field. Suitable scales for this interpretation are marked on the traces. Location of stations are No. 1: 28° N, 69° 40′ W; No. 5: 27° 50′ N, 70° 40′ W; No. 20: 27° N, 69° 30′ W.

Jean H. Filloux

and salinity is gained. Also, the oceans and atmosphere provide a natural "laboratory" in which many of the theories concerning fine-scale turbulent motion can be tested at large Reynolds numbers. Much of the instrumentation was developed in their own group. Most of the atmospheric measurements were made from the R/P FLIP, while the ocean measurements were made by towing the instruments from research ships, such as the *Oconostota* and the *Thomas Washington.*

Theoretical studies of wind/wave interactions carried out over several years by Dr. Russ E. Davis have culminated in the conclusion that the inadequacy of theories of wave generation is due predominantly to failure to properly appreciate the role of turbulence in establishing the airflow over waves. These studies have led to the conclusion that the phenomenologically motivated concept of an eddy-viscosity has a dynamical basis and a prediction of the value of the viscosity parameter which appears to be in agreement with observations. This exciting discovery suggests that the general theoretical method may be of interest in the study of a broad class of turbulent flow problems. Dr. Davis is now examining the validity of the seemingly severe statistical hypotheses involved in the theory.

Dr. Davis' participation in MODE (Mid-Ocean Dynamics Experiment) involved applying analysis of surface and internal wave measurements and mesoscale eddy data, along with data-adaptive analytical schemes, to real data. In this connection some analysis of density data obtained by the MODE program demonstrated some of the major features of the mesoscale eddies observed in the experiment, such as the finding of westward propagation velocities of approximately 4 km/day, apparently isotropic eddies in the main thermocline with scale lengths of the order 150 km, and anisotropic eddies in the deep water with north/south and east/west scales of 200 km and 100 km, respectively.

Drs. Jean H. Filloux and Charles S. Cox are using measurements of electric and magnetic fluctuations in the ocean to infer features of the ocean motion and the structure of the sea floor and mantle rocks. The electric field in the deep sea is caused by (1) large-scale oceanic barotropic motions, and (2) induction from magnetic storm pulsations in the ionosphere. It is possible to disentangle these sources because the oceanic motions are associated with much lower frequency phenomena than are the magnetic storms.

A second shelf station, installed at the head of nearby Scripps Submarine Canyon, is equipped with a current meter, a pressure sensor, and thermistors to provide data concerning the occurrence and intensity of currents in the canyon. Dr. Inman is studying the generation of strong currents in submarine canyons and has found that they are related to the interaction of the incident waves and standing edge waves that are trapped by irregularities in coastal topography.

Dr. Clinton Winant and graduate student Scott Jenkins measured temperature fluctuations in nearshore waters, and noted the occurrence of periodic events in which a significant thermal gradient exists in the water column (see illustration).

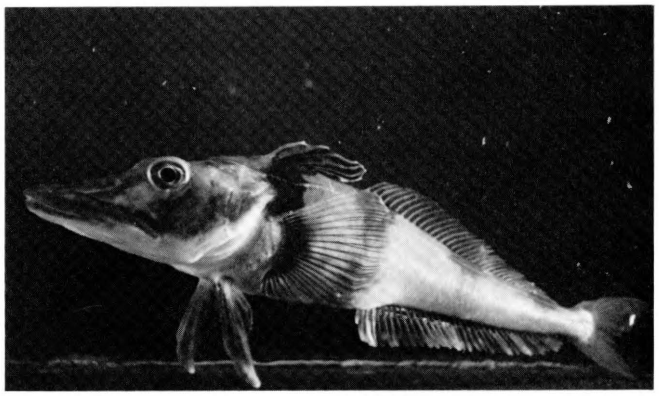
Studies have also been carried out concerning the conditions for the onset of sand grain motion and the bed forms created on a sandy bottom by waves. Using a narrow-beam sonar profiler, John Dingler, a graduate student, has developed the field procedures for rapidly and accurately measuring sand ripples created by waves. Graduate student Robert Guza is studying shoaling waves and the edge-wave modes on sloping beaches in the Hydraulics Laboratory.

Dr. Inman, Rolland Harris, dredging consultant; and Burton Adams, associate development engineer, are conducting a two-year field study at Oceanside Harbor; the goal is to improve technology for moving and transferring sand. Studies include the crater-sink sand-transfer system, supplemented with an advanced fluidizing technique called "duct flow," developed in the granular-fluids test basin at the Hydraulics Laboratory. In this process, graduate students James Bailard and Ron Oda are developing the theoretical aspects of this program.

"Duct flow" fluidization shows promise not only for effectively increasing the capability of a crater-sink bypassing system, but also as a practical tool for maintaining lagoon openings (see illustration).

Physiological Research Laboratory

The blood of the Antarctic cod *Dissostichus mawsoni,* like other Antarctic fishes, is fortified with novel glycoproteins that serve as "antifreezes" and permit them to avoid freezing at -1.9°C, the temperature of the water in McMurdo Sound. A field party under the direction of Dr. Arthur L. DeVries, of the Physiological Research



Dr. Edvard A. Hemmingsen continued studies of respiratory and circulatory adaptations in Antarctic icefishes (of the family Chaenichthyidae*) in response to complete lack of hemoglobin in their blood. Icefish shown here,* Chaenocephalus aceratus*, is about 60 cm long.*

Dr. Edvard A. Hemmingsen

Laboratory (PRL), studied this unique adaptation in Antarctica in 1973.

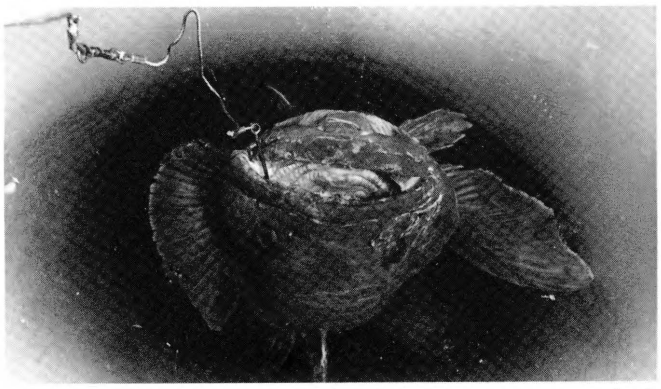
The distribution of the glycoproteins within the fish was determined by using radioactive-labeled glycoprotein antifreezes of several molecular sizes that were prepared in the laboratory. They were found in the coelomic fluid, pericardial fluid, and intracellular fluid, but neither in the bile nor in the urine. The absence of the smallest glycoproteins (molecular weight of 2,600 daltons) in the urine is extremely unusual, because in most vertebrates the process of urine formation involves filtration of water and small solutes from the blood into the urine by the many glomeruli in the kidneys.

When inulin, a polysaccharide of a molecular weight of 5,500 daltons, is introduced into the blood of most animals, it is quickly filtered by the glomeruli into the urine. In the Antarctic fishes the inulin was always retained in the blood, thus indicating that kidney glomeruli are absent. Microscopic observations of serial sections of kidney preparations have confirmed the discovery that they are, indeed, aglomerular. The Antarctic fishes maintain high levels of glycoproteins in their blood (4 percent W/V) because no filtration occurs in their aglomerular kidneys.

The notoheniid fishes of McMurdo Sound exhibit a swimming pattern that differs from that found in most other fishes. At slow sustained speeds these fishes propel themselves by their large fan-shaped pectoral fins and use their tail only for steering. The tail is used for swimming in brief bursts to escape predators. The musculature that covers the pectoral girdle and articulates the pectoral fins is red, while that associated with tail movement is white. In other fishes both red and white muscles drive the tail and their functions cannot be easily separated.

The distinct localization and specific function of the red and white muscle masses in these Antarctic fish is obvious. They are ideal subjects for relating function to metabolic requirements. Measurements of oxygen consumption of the red and white muscle from *D. mawsoni* showed that the consumption of red muscle is seven times higher than that of white muscle at their environmental temperature of -1.9°C. Electron micrographs of the red muscle reveal that the interfibrillar region is filled with large numbers of lipid droplets surrounded by mitochondria, and that very few glycogen granules are present.

Freezing resistance in several fishes inhabiting the waters of the northeastern part of North America was investigated. Graduate student John G. Duman demonstrated that the serums of these fishes have different melting and freezing points, a fact that indicates the presence of antifreeze compounds. Such a compound, isolated from the winter flounder, *Pseudopleuronectes americanus,* is a relatively large molecule. In contrast to the glycoprotein structure of serum antifreezes found in the Antarctic fishes, this one is a protein. This discovery is of particular interest, because it reveals the fact that fishes from these different geographical areas have evolved rather different, freezing-protectant compounds. Dr. DeVries and his associate, Dr. Yuan Lin, have found, further, that these antifreeze compounds cause freezing-point depression in a remarkable way that preserves the ionic and osmotic balance essential for life of the fish.



This giant Antarctic cod, Dissostichus mawsoni, *was caught by Physiological Research Laboratory party through seven-foot-thick ice on baited set-line at 500 m in McMurdo Sound, Antarctica. Largest of those caught weighed about 140 pounds.*

David Dyer

The program and the scientific supporting operations of the research vessel *Alpha Helix* are directed by Dr. Walter Garey, of the Physiological Research Laboratory. The Laboratory ship *Alpha Helix* operates as a national facility, and has been engaged in studies of experimental biology and medicine by scientists from throughout the United States and the world. An account of the operations and research activities of the *Alpha Helix* during 1972-73 appears elsewhere in this report. A booklet describing the ship and its program, and containing the abstracted field reports of studies carried out in 1972-73, may be obtained by contacting the *Alpha Helix* office in the Physiological Research Laboratory.

Regulation of body temperature in vertebrates is accomplished by temperature-dependent neurons in the basal forebrain and hypothalamic nuclei. Dr. Harold T. Hammel and his associates are studying the reactions of this control center to sensory inputs from temperature receptors in the skin and how they activate behavioral and autonomic thermoregulatory responses.

Harbor seals obtained as pups when R/V *Alpha Helix* was in the Bering Sea in Spring 1972, were implanted with thermodes surrounding the preoptic and anterior hypothalamic nuclei in the rostral forebrain. With these, James E. Maggert and Dr. Hammel experimentally cooled and warmed the thermoregulatory tissue from 33 to 42°C while measuring oxygen consumption and the body temperatures of the restrained animals exposed to temperatures from -10 to +30°C. The shivering response, as measured by oxygen consumption, was characterized by shivering response curves which all had the same hypothalamic threshold temperatures and had slopes that increased with decreasing rectal temperature. Ambient temperature, and therefore skin surface temperature, did not directly affect the threshold or slope of the shivering response curve. Dr. Kenneth R. Morgareidge has implanted a pair of thermodes astraddle the tissue lying between the optic chiasm and anterior commissure in the rostral brainstem of the box turtle *Terrapene ornata.* Heating this tissue elicits thermoregulatory salivation, thus illustrating that autonomic as well as behavioral responses may be affected by temperature of the regulatory center in reptiles as well as in mammals.

Dr. Hammel led a study of Adélie penguins in Antarctica. Fifteen penguins were implanted with two pairs of thermodes surrounding their hypothalamic tissue. The penguins were returned to PRL for continuing investigations of thermoregulatory and osmoregulatory responses to altering the hypothalamic temperature. Only slight thermoregulatory responses to heating and cooling the hypothalamic tissue were observed. On the other hand, the activities of the bird's nasal salt glands were readily stimulated by heating and inhibited by cooling the hypothalamic tissue. The successful adaptation of seals and penguins to the thermal rigors of Antarctic life is providing physiologists with dramatic examples useful for understanding human thermoregulation in health and disease.

The inimitable Adélie penguin of Antarctica was the subject of much research by Physiological Research Laboratory investigators. The successful adaptation of seals and penguins to thermal rigors of Antarctic life is providing physiologists with dramatic examples for understanding human thermoregulation in health and disease.

Frank Todd, of Sea World

Dr. Edvard A. Hemmingsen continued his investigations of the respiratory and circulatory adaptations in the Antarctic icefishes (of the family *Chaenichthyidae)* in response to the complete lack of hemoglobin in their blood. The adaptations include a substantial decrease in the metabolic rate and a severalfold increase in the blood volume and cardiac output compared with that of other cold-water fishes. Decreased vascular resistances in the gills and the tissues, coupled with decreased blood viscosity, allow the icefishes to increase the blood flow with a minimal increase of cardiac work. Circulatory responses to certain hypoxic conditions among icefish species imply that other adaptations within this group of remarkable fishes may have occurred.

Other research activities by Dr. Hemmingsen are concerned with properties of gases in solution in water and biological fluids at high gas pressures, with particular emphasis on the cavitation properties of highly gas-supersaturated liquids. The properties of dissolved gases in water and biological fluids are important relationships in marine animals. At high hydrostatic pressures and high gas pressures, the cavitation properties of gas-supersaturated liquid are of concern in understanding the physiological processes in deep-ocean species. Dr. Hemmingsen is involved in both theoretical and experimental studies of cavitation processes as they relate to life in extreme environments.

The theme of the behavioral, physiological, and anatomical adaptations that have occurred in vertebrates that swim at high speeds and dive to great depths underlies the studies of Dr. Gerald Kooyman. His work with aquatic vertebrates deals with the structural nature of lungs and how they relate to the gas exchange and ventilation requirements of these remarkable animals.

A survey of the microstructure and airway branching of the lungs of marine mammals and reptiles is in progress. In collaboration with Dr. David Denison, now at the RAF Acromedical Research Laboratory, a study of pinniped and sea otter lungs was completed. From this work it was learned that the lung microstructure of seals seems the least different from terrestrial mammals and sea lions, the latter of which are very similar in airway structure to those of whales. In an attempt to understand better what these structural variations mean, the mechanical properties of the lungs of bearded seals and walrus were studied during an *Alpha Helix* expedition in the Chukchi Sea. The field work of this project was carried out by Dr. Dan Kerem, of Duke University. Further work is anticipated during the summer of 1974, in cooperation with the University of Alaska.

Dr. Kooyman believes that some of the anatomical modifications may be caused by the unusual ventilatory needs of the animals, such as the explosive blows of the whales. In order to understand the physical nature of the blow, such as its duration, the gas flow rate, and the tidal volume, special pneumotachygraphs are being designed and constructed with the assistance of Dr. David Leith, Harvard University. While participating in Kenneth S. Norris' (UC-Santa Cruz) grey whale expedition to Baja California, Dr. Kooyman made detailed observations of ventilatory behavior of cow and calf under a variety of conditions, and successfully used one of the new pneumotachygraphs.

Because the function of lungs can be better understood by studying their structural development, Dr. Kooyman is studying lungs from developing fetuses of spotted and spinner dolphins. Robert Garvie, a graduate student of UCSD's School of Medicine, has made two cruises aboard tuna seiners to collect and preserve fresh material and to characterize the mechanical properties of the lungs of adult animals.

Sea turtles and sea snakes are faced with many respiratory problems that are similar to those of marine mammals. The lungs of reptiles are much simpler, however. Consequently, a major study of the effects of compression on gas exchange in yellow-bellied sea snakes will be done in Panama in collaboration with Dr. Jeffrey Graham of the Smithsonian Tropical Research Institute.

Mrs. John D. Isaacs, left, chairman of the People-to-People exchange program, presents to Scripps Librarian William J. Goff a bound volume of research papers prepared by oceanography students of Escuela Superior de Ciencias Marinas, University of Baja California, Ensenada. Prof. Carlos R. de Alba-Perez, right, school director, earlier had given the volume to People-to-People — a women's international-relations interest group of UCSD Oceanids, which is comprised of wives and women faculty members — during annual visit to Scripps by students, instructors, and their wives from Ensenada school.

Dr. Per F. Scholander's studies of the osmotic properties of water in plant and animal tissues have led to new methods for their measurement and to new concepts of their physical origin. The tensile state of water in these systems has been demonstrated in many ways, the most recent involving use of ferromagnetic solutions in magnetic fields. The osmotic pressure of the solution could be altered by placing a magnet above or below the solution. Current concepts of the nature of solute effects upon osmotic pressure and other properties of solutions have been revised as a result of these studies, and a monograph on the subject is being readied for publication.

Much of marine life proceeds at the great pressures of the deep sea. Dr. Aristides A. Yayanos is studying the molecular bases of adaptation to such hyperbaric conditions.

First, examination of the thermodynamic relationships underlying deep-sea phenomena is continuing with the determination of the pressure dependence of partial molal volumes. A large pressure effect on the partial molal volume of magnesium sulfate as an important component of seawater and biological fluids has been observed. Theoretical bases of biological consequences of this large pressure effect are being explored.

Second, an investigation into the pressure sensitivity of protein-protein interactions has been initiated with the determination that the trypsin-trypsin (ovomucoid) reaction is relatively insensitive to pressure changes as great as 2,000 atm. Finally, the process of bacterial cell division and its relationship to DNA synthesis has been studied at high pressures. A high-pressure device has been constructed that can retrieve organisms from the greatest depths of the sea and maintain their native pressure and temperatures. It will soon be possible to study cellular processes in living deep-sea organisms, the better to understand their remarkable adaptations to high pressure.

Shipboard Computer Group

The Shipboard Computer Group (SCG) of programmers, engineers, and technicians supports four IBM 1800 computers and, as required, other computer systems at Scripps through programming, interface design, and maintenance. Computers are installed permanently on the R/V *Thomas Washington* and R/V *Melville* and ashore in Ritter Hall. During 1972-73, a computer was also operated on the Woods Hole Oceanographic Institution's R/V *Knorr* by the GEOSECS group and by SCG.

The computer systems are equipped with printers, card readers, typers, plotters, disk memories and magnetic tape units for batch-processing and real-time data storage, and processing and display. They are interfaced to a ship's course and speed and satellite navigation receivers for precise determination of data location. Scientific instruments interfaced to the computer for automatic data acquisition and storage include STDs (Salinity/Temperature/Depth probes), XBTs (Expendable Bathythermographs), magnetometers,

transponder-ranging inputs for the Marine Physical Laboratory's Deep-Tow vehicle, and radio-relayed, sonobuoy, seismic refraction 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.

Using a new 13-m water tank installed at the Visibility Laboratory's Point Loma facility, investigators explore in detail the water properties affecting image propagation and perform controlled tests on new instruments for optical oceanography.
Visibility Laboratory

Visibility Laboratory

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

Optical Oceanography

Research related to the propagation of light in seawater remains the largest single activity of the Visibility Laboratory. Drs. Seibert Q. Duntley and Wayne H. Wilson have continued their experimental exploration of the manner in which water degrades the quality of in-water photographs. A laser was used to form a submerged point source that was imaged through water. The structure of the image was documented by photoelectric measurements. This research was performed in a tank in which the optical properties of the water could be varied at will throughout the experiments. The data led to mathematical functions of a type that is useful in the computer synthesis of any type of image and to assessment of its usable information content.

Needs for increasingly detailed and comprehensive data on the optical properties of ocean waters led Roswell W. Austin and Theodore J. Petzold to develop improved instrumentation. It is a long-range goal of their measurement programs to expand the present optical-data base geographically and seasonally. This, coupled with continuing study of the mechanisms which determine water clarity and cause its changes, may lead to a capability for forecasting visibility conditions in the oceans. Dr. Raymond C. Smith analyzed spectral irradiance and radiance distribution data from the Gulf of California to determine the structure of solar radiation in the upper layers of the sea. Data from the Sargasso Sea, Crater Lake, and Lake Tahoe were used by John E. Tyler, Dr. Smith, and Dr. W. H. Wilson to formulate a prediction model of the optical properties of clear, natural water. The lake data were also used for a color analysis of the two lakes, noted for their esthetic appearance.

Members of the Scientific Committee on Oceanic Research (SCOR) Working Group 15, chaired by Tyler, unanimously approved several recommendations that were accepted by SCOR president, Professor Dr. H. Postma, of Texel, The Netherlands. The recommendations, which substitute a measurement of the total quanta available for photosynthesis in place of the less-well-defined quantity previously used, should result in a more fundamental understanding of the process of photosynthesis by marine phytoplankton.

Under the direction of Austin, the Laboratory continued its studies of oceanographic information which can be extracted from remotely sensed optical data. Improved computer modeling of such data was accomplished by Wilson. This incorporates the vertical distribution of phytoplankton in the water, detailed reflectance properties of the sea surface, the distribution of white water as a function of wind velocity, the obscuring properties of the atmosphere, and lighting conditions. One goal of such modeling is the hope of developing valid means for remotely assessing the phytoplankton crop in the euphotic zone of the sea.

Atmospheric Studies

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

Two major field expeditions were carried out during the year under the leadership of Richard W. Johnson. The first, designated Project Gateway, was a 24-day deployment in southern Illinois during January, 1973. Coordinated airborne and ground-based measurements were made of daytime atmospheric optical and meteorological properties in the vicinity of St. Louis, Missouri. This is the same location in which a previous Visibility Laboratory expedition using the C-130 aircraft and its ground station measured summer conditions in support of the METROMEX program, a national research effort which seeks to determine the effects of urbanization upon weather.

The second field expedition, designated Project HAVEN VIEW II, was a 58-day deployment to northern Germany during May and June, 1973. It also was a combined airborne and ground-based research. In addition to the Laboratory's planned experiments, the aircraft flew several special atmospheric profiles in cooperation with a U.S.-sponsored visibility experiment by the German Research Institute for Aeronautics and Space. During these special missions, a team of host-nation observers performed a ground-to-air visual search for the C-130 aircraft while the Visibility Laboratory airborne and ground-based systems documented the optical atmospheric and lighting condition.

Research Utilizing Image-Processing Facilities

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

Under the direction of Benjamin L. McGlamery and with collaboration by Wilson, a computer-simulation system for synthesizing in-water imagery is being developed. When completed, the system will produce photographs which appear as if they were actually taken in water. The user will be able to specify a light source with its angular distribution, a camera type and its location, and the scattering, ab-

sorption, and stratification properties of the water. The computer-simulation system will mathematically determine how each of these factors alters the image and will produce accurate computer-generated pictures showing how any type of underwater scene will appear when photographed by the assumed light and camera system. The new simulation capability will be an important tool for evaluating existing in-water, light-and-camera combinations, as well as for optimizing the design of new systems. Thus, any proposed in-water camera and lighting system can be given accurate performance trials before it is built, and the suitability of any existing equipment can be ascertained before its deployment.

McGlamery has also continued the development of computer techniques to improve the quality of imagery which has been degraded by the atmosphere or by defects of the collecting optical system.

James L. Harris, Sr., has continued his use of the image-processing facility to study various aspects of aircraft safety. Particular emphasis was placed upon a study of the extent to which the pilot can rely upon his eyesight for the detection and avoidance of other aircraft. This visual task has two separate parts. The first involves search for and visual acquisition of the other aircraft. The second portion of the task involves a quantitative interpretation of the visual stimulus to yield an estimate of the expected flight path of the threat aircraft and a determination of an appropriate evasive action if one is required.

Institute of Geophysics and Planetary Physics

The Institute of Geophysics and Planetary Physics (IGPP) is a University-wide Institute with branches at La Jolla, Los Angeles, Riverside, and Davis. The Institute at La Jolla is closely related to Scripps Institution, not only because of geographical proximity, but more importantly, because of common scientific interests.

Drs. George E. Backus, J. Freeman Gilbert, Richard A. Haubrich, Walter H. Munk, and Robert L. Parker hold joint appointments in IGPP and Scripps. Dr. James N. Brune and Sir Edward C. Bullard hold Scripps appointments; their offices are located at IGPP. Drs. Ralph H. Lovberg and Barry Block hold joint appointments in IGPP and the UCSD Department of Physics. Drs. Hugh Bradner and John W. Miles hold joint appointments in IGPP and UCSD's Department of Applied Mechanics and Engineering Sciences. Drs. Jonathan Berger, Peter H. Molnar, William A. Prothero, and Frank E. Snodgrass and Wendell S. Brown and Bernard D. Zetler have senior research appointments in the Institute.

Dr. Brune's work concentrated on seismic studies in Mexico, seismic studies of the source mechanism of earthquakes, studies of seismic hazard in the San Diego area, modeling of the ocean-floor spreading process using a wax model, and modeling the strong motion pattern of earthquakes using a stressed, foam-rubber model. Along with a graduate student, Alfonso Reyes, and in cooperation with Dr. Cinna Lomnitz of the National University of Mexico, and Fred Moser of the Mexican Federal Power Commission, Dr. Brune conducted two field trips to Mexico to study aftershocks of major earthquakes. In source-mechanism studies, in cooperation with graduate student Brian Tucker, the detailed seismic spectra of aftershocks of the San Fernando earthquake have been analyzed. These aftershocks are the first that have been available for study by both near-source, digital, high-fidelity recording and a large number of distant stations so that the near-source spectra could be compared with the surface waves recorded at large distances. In order to understand the pattern of strong motion expected around major earthquakes, a foam-rubber model has been set up containing dislocations that slip when they are stressed in the same manner as earthquakes. In this way the maximum particle velocities and accelerations are related to other parameters of the dislocation, for example, the stress drop and rupture velocity.

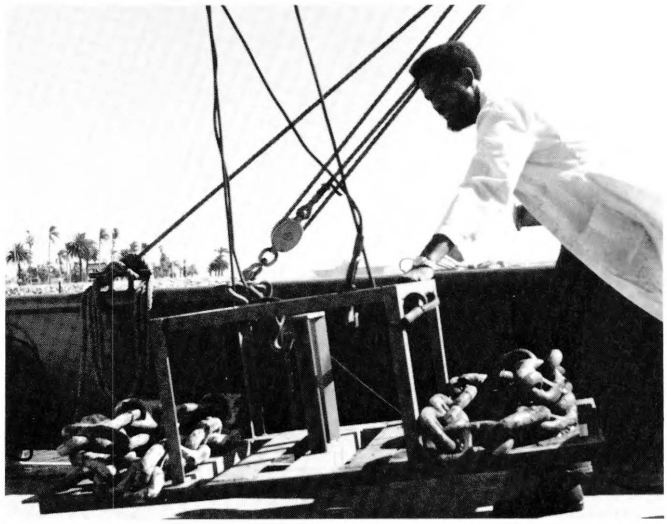
Dr. Bradner's research activities have consisted of the measurement of earthquakes using sonobuoys (with Dr. Brune and graduate students), and the development and testing of ocean-bottom seismographs (with Drs. Brune and Prothero and graduate students). Large numbers of oceanic earthquakes have been recorded from a wide variety of oceanic tectonic environments. In his study of ocean seismicity, Dr. Prothero's work consisted of developing, testing, and deploying a "pop-up," ocean-bottom, seismometer capsule containing a 1 Hz vertical seismometer and triggered digital recording system.

Dr. Gilbert's research continued in the observation of the earth's normal modes, the interpretation in terms of the mechanical structure of the earth, and the retrieval of the source mechanism of earthquakes. At present, 1,064 distinct normal mode frequencies have been observed. It appears from solutions of the inverse problem that the mechanical structure of the earth is very well constrained in detail at depths below 950 km and is constrained in a gross average sense above that depth. In addition, the source mechanism of two deep earthquakes has been found, and it appears that both contain a significant compressive component; furthermore, the compressive component may precede the onset of the main shock by a minute or so.

Dr. Parker has been concentrating on the interpretation of potential-field measurements and in a cooperative program with the Marine Physical Laboratory, has developed methods for constructing magnetization models of the sea floor using observations made near the bottom with the Deep-Tow vehicle. The large signals associated with the bottom relief are properly accounted for in these models. Dr. Parker is currently working with Dr. John D. Mudie and two graduate students, Kim Klitgord and Stephen Huestis, on the geological and geophysical implications of the models. Another topic in potential theory, which Dr. Parker has been studying, is the extraction of information from gravity data with the introduction of a minimum number of assumptions. He has proved a theorem that enables one to estimate best possible density and depth bounds from any discrete collection of gravity observations. This result may be of practical value in exploration geophysics.

Dr. Berger continues his study of the seismo-tectonics of Southern California, using, primarily, data obtained at the Piñon Flat Geophysical Observatory. The Observatory has been completed with the installation of the second and third arms of a laser strain meter. Fully operational instrumentation now includes a superconducting gravimeter, a La Coste modified gravimeter, aa quartzfibre gravimeter, an array of eight tiltmeters, three-component, long-period seismometers, and various environmental monitoring equipment.

Drs. Munk and Snodgrass and Brown and Zetler conducted pre-MODE (Mid-Ocean Dynamics Experiment) experiments in the Pacific and later participated in the bottom experiment of MODE southwest of Bermuda. They discovered quite large pressure fluctuations on the sea floor, with horizontal scales of several thousand kilometers. Deep-sea tides were measured to great precision. The internal wave model of Dr. Munk and Dr. Christopher Garrett of Dalhousie University, Halifax, Nova Scotia, was applied to the problem of shear stabil-

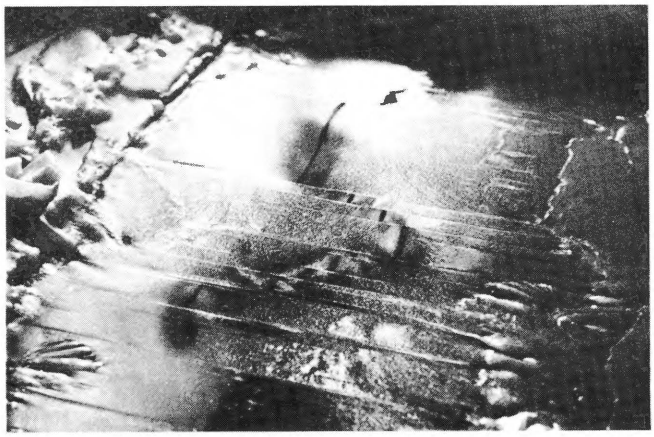


Amos Lewis, electronics technician at Institute of Geophysics and Planetary Physics, loads battery frame and anchor chain aboard R/V Ellen B. Scripps. *Equipment was lowered into ocean as part of instrumentation used to measure internal ocean waves.*

ity and resultant mixing in the deep ocean's interior. Graduate students James Cairns and Gordon Williams, supported by the Advanced Ocean Engineering Laboratory, used a mid-water version of the Snodgrass capsule to measure internal waves and the evolution of microstructure; the experiment produced some unanswered questions concerning the dynamics of free capsules. In the development of a one-year capsule, a solid-state memory has been incorporated in the prototype. Wave-directional spectra have been inferred from radio backscatter, using a synthetic aperture technique on Wake Island. Some attention has been given to the role played by internal waves in the transmission of sound, and this has led to the description of a canonical sound channel.

Dr. Miles worked specifically on the tsunami response of harbors and bays, and on the foundations of Laplace's tidal equations. A comprehensive review of "Harbor Seiching" was prepared for the *Annual Review of Fluid Mechanics*. A critical study of Laplace's tidal equations was undertaken (subsequently completed and submitted to the *Journal of Fluid Mechanics*).

Dr. Lovberg's development of a new, optical, earth strainmeter, based on mode-locked operation of a very long laser, has progressed nearly to completion of the instrument. The long laser has been made to operate satisfactorily with approximately 1 watt of optical power circulating within the 800 m optical cavity. Measurements of the low-frequency spectrum of laser power show strong components at the beat frequency between adjacent axial modes (210 kHz) and at the first four higher harmonics; thus, the essential conditions for mode locking have been achieved.



Upper *figure is a map of Mid-Atlantic Ridge between Africa and South America which displays characteristic orthogonal pattern of ridges and transform faults.* Lower *figure is photograph taken from Oldenburg and Brune (1972), of an orthogonal pattern generated in a laboratory model by using candle wax. Upper photo: Copyright 1971 National Geographic Society; lower photo: Douglas W. Oldenburg.*

Dr. Backus continued his geophysical research. His areas of interest included (1) some problems in linear algebra related to calculating earth normal modes in which the earth's rotation cannot be treated as a small perturbation; (2) a proof of a uniqueness theorem for obtaining the geomagnetic field from satellite observations; (3) assorted solutions of non-linear and linear-steady, viscous-flow problems related to the asthenosphere, along with some stability analyses; and (4) an attempt, not yet successful, to calculate some exotic aspects of the seismic signal from a double-couple source in a real earth.

Dr. Haubrich has been primarily concerned with excitation sources of earth wobble. The rotation axis of the earth moves with a 14-month circular resonant motion called the Chandler Wobble. Since the motion would damp out after a time if unexcited, some, as yet unknown, large mass displacements within or on the earth must be responsible for the observed wobble. One possible source is earthquakes; no significant correlation has been found between the earthquakes and the Chandler Wobble, however. Another source considered was atmospheric pressure variations. The cross spectrum between the pressure excitation and the deconvolved pole position showed a suggestion of correlation between the two. A recalculation of the pressure excitation from observed air pressures is now in progress, since it was found that the results of this numerical integration are highly dependent on assumptions and approximations used in the numerical methods.

Institute of Marine Resources

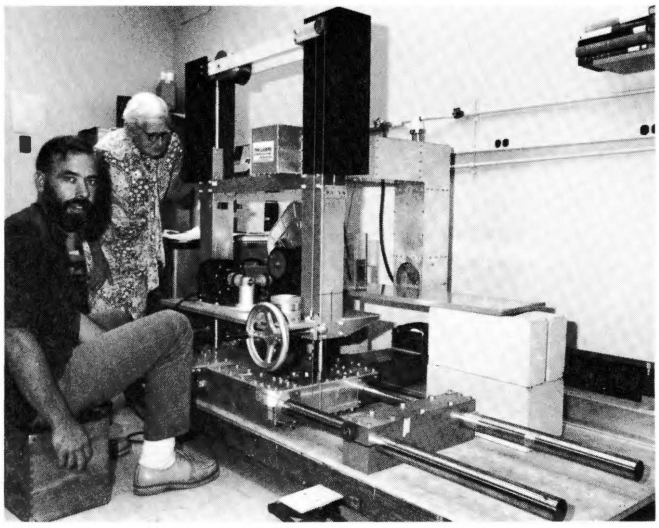
The Institute of Marine Resources (IMR) is concerned with research, education, and public service in the broad area of marine resources utilization. IMR provides a study basis for improving the supply of organic and mineral materials and it fosters the gathering and dissemination of knowledge about such other resource aspects as transportation, disposal, pollution, and recreation. It also provides for research into the social, legal, economic, and political aspects of man's related activities.

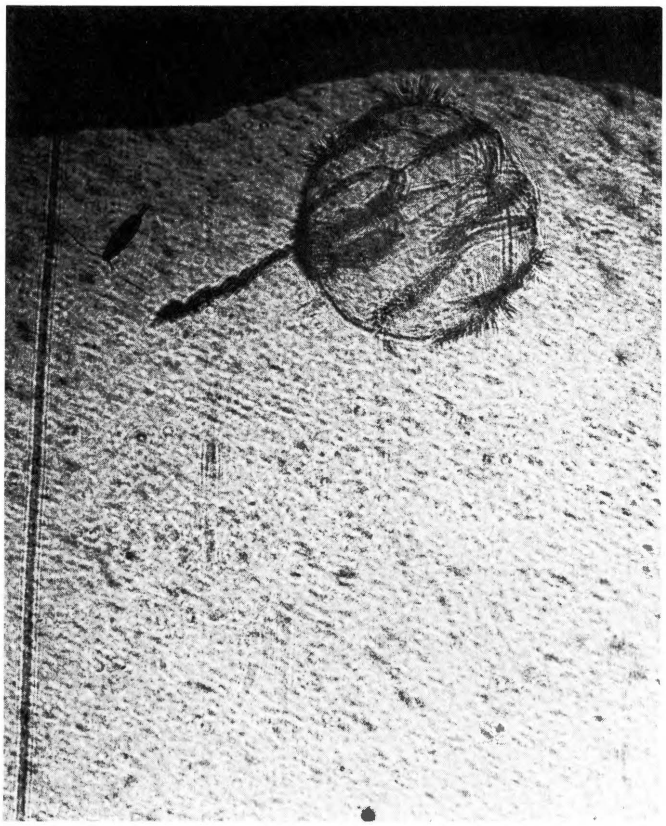
The Institute has facilities on several UC campuses, and is administered from the S10 campus. Its activities during the year were supported by a budget of $206,886 and by contracts and grants of $2,406,820, the latter including the Sea Grant College Program budget for all of UC and San Diego State University, which IMR administers. An executive committee comprising faculty members and an advisory council consisting of public members, appointed by the president of UC, assist the IMR director on policy and on plans for research activities.

IMR scientists and those affiliated with IMR carried out research in many disciplines. Mentioned briefly here are only the more cohesive studies and only those undertaken at Scripps. A full account is given in the annual reports issued by IMR, the Food Chain Research Group, and the Sea Grant College Program.

Food Chain Research Group

As its principal field program, the Food Chain Research Group (FCRG) continued its study of plankton dynamics in the central gyre of the North Pacific, along with members of the Marine Life Research Group (MLRG). The economy of phosphorus and nitrogen was examined in detail, as these two elements are present in vanishingly low abundance in the gyre surface waters where phytoplankton grow. Earlier Dr. Elizabeth Venrick (MLRG) had noted that several species of the diatom genus *Rhizosolenia* in these waters contained an endophytic blue-green algae, *Richelia* intracellularis. A "bloom" of the diatom was encountered in June that allowed quantitative study of nitrogen fixation rates by Dr. Timothy H. Mague and his colleagues of the FCRG. Assimilation rates of ^{15}N labeled ammonium, urea, and nitrate by phytoplankton are now routine measurements on the gyre cruises (Dr. Jon H. Sharp and colleagues) as are the rates of excretion of nitrogen-containing wastes by zooplankton (Dr. Michael M. Mullin and colleagues). Most of the nitrogen assimilated by the plants may be proximally derived from zooplankton excretion. Little of it arises from mixing of deep, nutrient-rich water or from nitrogen compounds in rainfall. Losses from sinking may be restored by nitrogen fixation in





Holographic, i.e., *a three-dimensional image recording, techniques are utilized by Food Chain Research Group, Institute of Marine Resources, to study marine plankton. One figure shows Gene L. Stewart operating cineholocamera system as Dr. Sheina M. Marshall, Marine Laboratory, Millport, Scotland, a visiting investigator, observes. The other is a photograph of hologram reconstruction of a ctenophore,* Pleurobrachia. *An "out-of-focus" copepod is seen at lower left. In reconstructing a hologram, any depth within the scene can be brought into as sharp a focus as is desired, for detailed examination.*

Food Chain Research Group

the summer season when blue-green algae, such as *Richelia* and the free-living *Trichodesmium,* are present.

Estimation of standing stocks of plankton of various categories is made from adenosine triphosphate analysis (Dr. Osmund Holm-Hansen) and from direct counts of organisms (Dr. John R. Beers for protozoans and other microzooplankton; Freda M. Reid for phytoplankton). James B. Jordan has isolated into culture several species of phytoplankton from the gyre for subsequent laboratory study.

Work in the home laboratories has continued. Dr. Peter M. Williams, in collaboration with Dr. P. J. Kinney, University of Alaska, has new data on the ^{14}C age of dissolved organic matter in seawater. Dr. Angelo F. Carlucci has isolated several bacteria with remarkable abilities to grow on extremely low concentrations of organic matter. Dr. Farooq Azam has been busy with the kinetics of utilization of organic matter by bacteria, particularly using tritiated compounds as substrates. Numerous related projects were carried out by Scripps students associated with the FCRG. These have in common the goals of (1) improving the methodology for measuring plankton and its activities, such as zooplankton feeding, phytoplankton nutrient assimilation, and the use of holography to visualize plankton behavior; and (2) furthering the conceptual base for understanding the planktonic food web via studies of the mechanism and the development of models for plankton processes.

Center for Marine Affairs

In September, the Center for Marine Affairs (CMA) became a part of the Institute of Marine Resources. Dr. Warren S. Wooster, first director of CMA, resigned during the year and was replaced by Dr. Gerald L. Wick, who is also assistant director of IMR.

The results of the first CMA study on oceanic research in foreign territorial waters were published in 1973 by Crane, Russak & Co. as a book, *Freedom of Oceanic Research.*

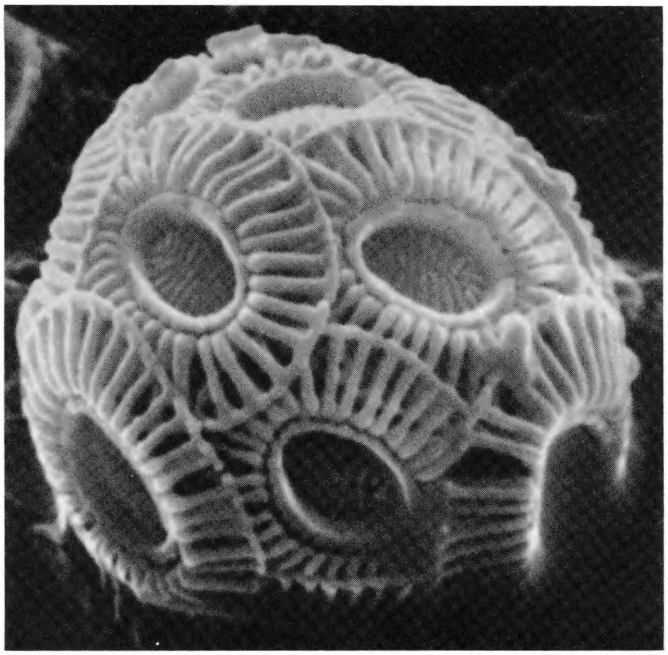
The year saw completion of the second study by CMA personnel on Marine Science and International Pollution Policy. Results of the study are published in these three papers: "Scientists and Policy Makers; A Case Study in the Ethnography of Communication," by H. R. Bernard; "The Science Advisory Function: The Case of International Marine Environment Policy," by M. Brenner; and "Toward a Global Regime for Ocean Pollution," by D. A. Livingston. Dr. Bernard investigated the relationship between scientists and bureaucrats and why these two groups seem to be frustrated by each other's advice and demands. Dr. Brenner critically analyzed the role of scientific advisors in the area of marine environmental policy. In his paper, Dr. Livingston portrays and evaluates the kind of global regime that appears to be evolving in order to deal with ocean pollution.

Four new Fellows were appointed to CMA in 1973 as the nucleus of a research team to conduct studies on the Control and Utilization of Environmental Extremes. They include two political scientists, an economist, and an economic geographer. This third CMA study examines long-range marine resource management issues related to desert coasts. The study focuses on the extensive desert coastline of Baja California in order to illuminate key marine resource management issues that have direct relevance to future resource utilization among desert coasts in general. CMA staff, in collaboration with Scripps scientists, is evaluating the potential of various technologies along the Baja California coastline and examining how scientific knowledge and technology can be used to assist the Mexicans. Other issues being investigated with regard to these desert coasts include the conflict inherent between short-term and long-term economic growth and development, the reconciliation of economic growth with conservation of the environment, and the relationship between national and international interests regarding resource utilization.

CMA researchers are also investigating the political and economic aspects of manganese-nodule mining and of the management of the California anchovy fishery and of the eastern Pacific tuna fishery.

Sea Grant Supported Projects at Scripps

The National Sea Grant College Program encourages the development of the nation's marine resources in both adjacent oceans, in the Gulf of Mexico, and in the Great Lakes through grants from the Na-



Magnification of 10,000X on Scripps's Analytical Facility's scanning electron microscope reveals intricate architecture of plates covering this coccolithophorid. Plate structure permits identification of this microscopic algal cell, a member of the ocean plankton. These cells are being studied by investigators of the Institute of Marine Resources' Food Chain Research Group.
J. M. Jordan

tional Oceanic and Atmospheric Administration of the U.S. Department of Commerce for projects in research and development, in education and training, and for advisory services. It fosters local participation by stipulating a one-third sharing of funding from non-federal sources.

IMR provides the aegis for the UC Sea Grant College Program. An overview of Sea Grant-funded projects at Scripps for 1972-73 indicates a quality and commitment for which the University's research, education and training, and advisory programs were granted recognition.

The Ocean Education for the Public Program at the Aquarium-Museum during 1972-73 intrigued and informed more than 50,000 schoolchildren and many adults, free of charge.

Dr. Victor C. Anderson, in addition to his continuing studies of the ORB-RUM (Oceanographic Research Buoy-Remote Underwater Manipulator) system, shepherded the Applied Ocean Science (AOS) graduate education project through its fifth and final year. Several new courses stimulated by the Sea Grant project have expended AOS's curriculum base. Dr. Clinton D. Winant joined the Scripps faculty in shore processes, a field involving the largest number of AOS students. Under the direction of Dr. Douglas L. Inman, the Shore Processes Laboratory, in a study of physical criteria for coastal planning, provided regional and state commissions with key elements in creating an improved design for living with California's nearshore marine resources.

Dr. Paul Dayton assumed responsibility for the ecological studies of the nearshore zone begun by Dr. E. W. Fager. He and his student assistants worked toward establishing base line and experimental knowledge of the community structure of nearshore communities, such as the San Diego-La Jolla Underwater Park, the Southern California kelp community, and the old and new discharge areas of the Orange County sewer outfall.

Aquaculturists investigated the cultivation of marine species from the lobster (Richard Ford/Jon Van Olst) to the abalone (Dr. David Leighton) and larval pelagic fishes (Dr. Reuben Lasker), whose rearing under controlled laboratory conditions has aided scientists in the studies of the effects on survival of environmental variables such as salinity, heat, and pollution.

Dr. James J. Sullivan directed a project aimed at modelling marine resources decision-making based on careful study of environmental impact both in theory and practice.

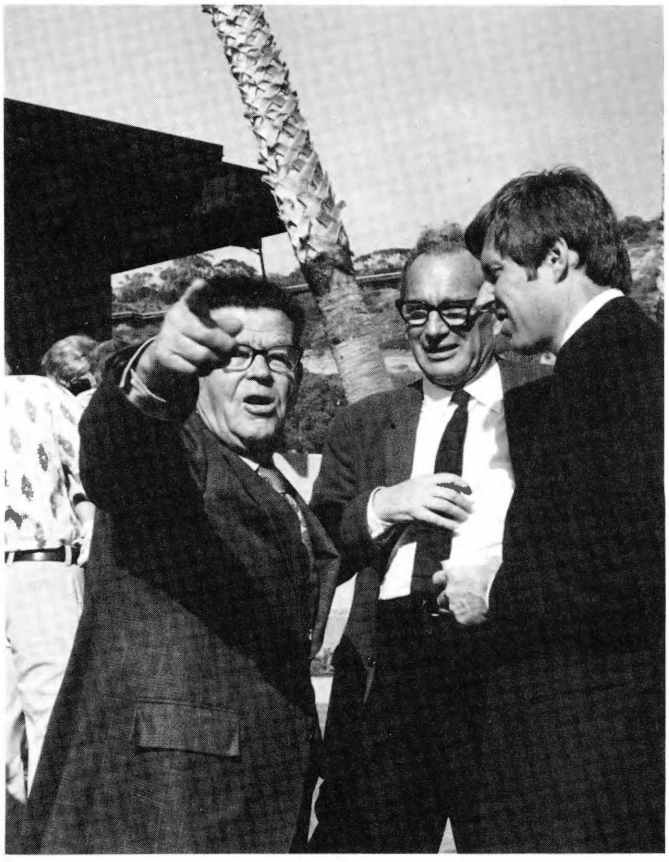
Dr. D. John Faulkner's work with an insect growth hormone administered to barnacles in the laboratory showed that the substance prevents fouling animals from adhering to a settling surface under controlled conditions.

The energy residing in waves inspired two related projects. The Isaacs/Castel wave-powered generator system was designed to assess the feasibility of extracting power from ocean waves. The opposite aim; namely, the dissipation of potentially destructive storm waves, is under test on the Isaacs/Seymour dynamic breakwater design, a tethered float breakwater.

The foregoing achievements are more fully reported in the UC Sea Grant College Annual Report 1972-73, which may be obtained by writing to Scripps Institution of Oceanography.

Nineteen graduate students, in a dozen provisions, received IMR support for research related to the mission of the Institute. Two of these researches culminated in doctoral theses, one on the effects of temperature and salinity on eggs and larvae of bairdiella fish and one on the quantitative natural history of a ctenophore. Abstracts of these and of ongoing or completed studies will appear in the *IMR Biennial Report,* which will be available from the Institute on request.

U.S. Sen. John Tunney of California, right, was principal speaker at dedication of Shore Processes Laboratory building. Here, follwing the brief program, he and Director Nierenberg listen to comments emphasized by Dr. Carl L. Hubbs.
Sue Price



SHORE FACILITIES AND COLLECTIONS

Facilities

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

The staff, assisted by nearly 80 volunteer docents, conducts a manifold educational program. More than 50,000 students annually tour the Aquarium-Museum in educational groups, and a career-experience program is offered to high school and college students considering an aquarium career. Federal Sea Grant funds support a full-time coordinator for educational programs.

Although admission is free, voluntary contributions from many of the more than 367,000 yearly visitors provide significant financial support.

New museum exhibits, expansion of educational programs, and an exhibit preparator are supported by gifts pledged to the Foundation for Ocean Research by the Southern California First National Bank for the benefit of the Aquarium-Museum.

Research is carried out on problems centering around maintenance of marine animals and coloration in fishes.

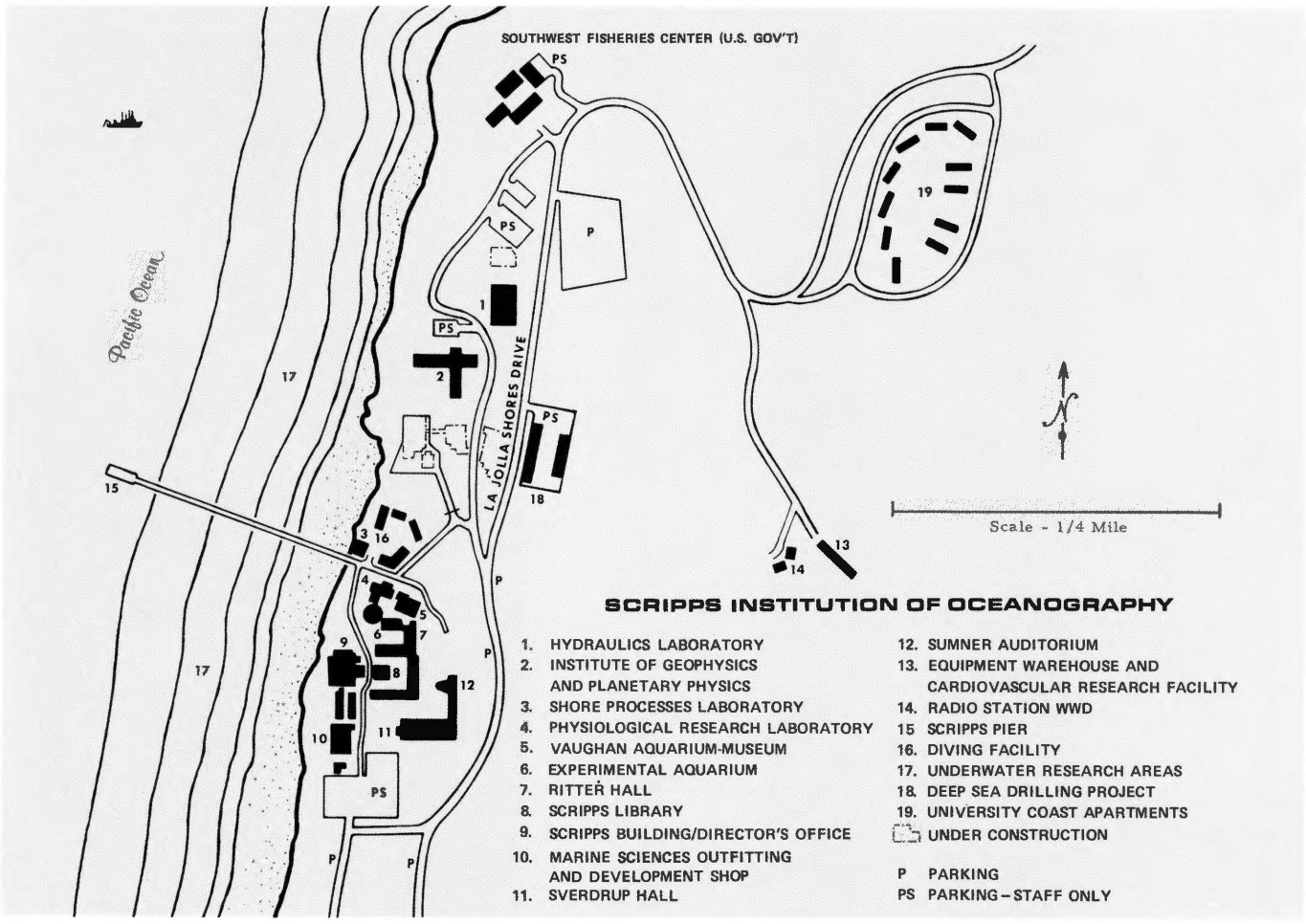
The Aquarium-Museum is free and open to the public daily.

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

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

Radio Station WWD (14). Licensed to the National Marine Fisheries Service and operated by Scripps personnel, Station WWD provides communications services to both organizations as well as to other government and institutional scientific ships. The station has worldwide capabilities. Voice, CW, radioteletype and facsimile transmissions can be handled by the station, which operates 12 hours a day, Monday through Friday, and 8 hours a day on Saturdays, Sundays, and holidays.

Scripps Library (8). The library houses a vast amount of oceanographic information with outstanding collections in oceanography, marine biology, and undersea technology. In addition to a basic collection of monographs and serials in mathematics, physics, chemistry, geology, and zoology, the main collection includes extensive expedition literature. As of June 30, 1973, the library held 97,900 bound volumes; 24,014 maps and charts; 20,611 reprints; 19,274 documents, reports, and translations, and 2,666 pieces of microcopy. The Documents/Reports/Translations Collection is comprised of a nucleus of technical reports and memoranda issued by Scripps and supplemented by reports and translations issued by other educational, governmental, and industrial institutions involved in marine research.



The Map and Chart Collection is a reference collection of atlases, nautical charts, and geologic and topographic maps. The collection emphasizes nautical information, and is a depository for U. S. Geological Survey, geologic maps and related publications. The library's Rare Book Collection has many old and valuable treatises and encyclopedias in science and natural history, as well as numerous accounts and journals of famous voyages of discovery.

Hydraulics Laboratory (1). This laboratory is equipped with a wind-wave channel 43x2.4x2.4m in size with a simulated beach and a tow cart for instrument and model towing; a 15x18-m wave basin with an adjustable simulated beach; a 40-m glass-walled wave-and-current channel; a granular fluid mechanics test facility consisting of a 6x12x3-m-deep concrete basin; a 10x1x1-m fluidizing channel; 3 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 are programmable and can be computer controlled. An IBM 1130 computer system is the central controller for data acquisition and data processing in conjunction with experimental use of various facilities.

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

Seawater System (15). The system provides seawater to Scripps and the Southwest Fisheries Center. It utilizes two sand filters and two concrete storage and settling tanks, each with a 200,568-l capacity. Delivery capacity is 1,135 l per minute.

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

Diving Facility (16). The diving facility, which has easy access to the ocean, consists of two separate areas. One contains separate space for men's and women's showers, dressing rooms, and personal diving equipment storage. The second is devoted to air compressors, a 1,113-l air volume bank, diving cylinder storage, and an overhaul and repair facility. An 11-m diving boat and a 5-m skiff are available to the diving facility.

Scripps's SCUBA diver training program, among the oldest diver training and scientific diving programs in the country, conducts a number of SCUBA training classes annually. These are generally limited to University personnel who have the need to work or study underwater, but federal, state, and local government employees may be admitted by special permission. Some 100 faculty and staff members and students are certified for underwater work; they make an average of 4,000 dives a year. The Institution has an 11-year total of more than 50,000 accident-free dives.

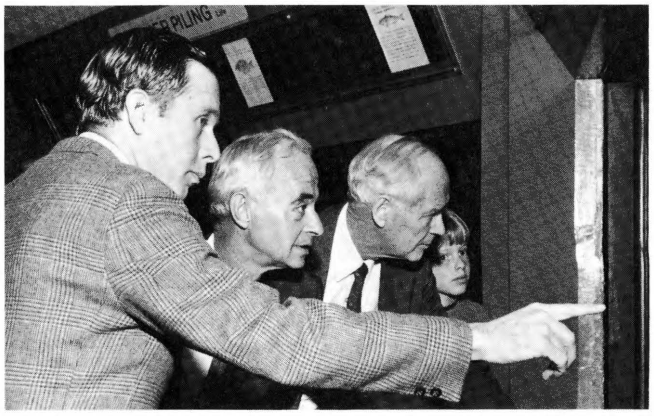
Electron Microscope Laboratory (7). Two Siemens electron microscopes, together with freeze-etching (Balzers) and accessory equipment, provide high resolution in the study of ultra-fine structure.

Analytical Facility (11). The facility was organized three years ago to provide the Scripps graduate student and staff with analytical instruments and professional assistance to aid in thesis or project research. Capabilities of the facility include an X-ray diffractometer for crystal lattice parameter and mineral identification; X-ray spectrometer for qualitative and quantative analysis of elements above atomic number 12; atomic absorption spectrometer (A.A.) for quantitative determination of elements in solution; heated graphite atomizer (attachment to A.A.) for determination of elements in solids with detection limits of $1x10^{-12}$ grams; amino acid analyzer for amino acid characterization; gas chromatograph for separation and identification of molecules in the gas phase; gas chromatograph/mass spectrometer for qualitative separation and analysis of organic compound; a Nova 1210 mini-computer for data handling; carbon dioxide analyzer for sample carbon and carbonate content in terms of carbon dioxide; scanning electron microscope for examination of samples at magnifications up to 100,000X enhanced by the depth of field far surpassing the light microscope. The facility offers complete sample preparation laboratories (including wet chemistry and rock processing laboratories, a table-top Olivetti computer, and geological field equipment).

Mass Spectrographic Equipment (7) (11). Eight mass spectrometers are available, including two 15.24-cm, Nier-type spectrometers for isotopic analysis of light elements; a 15.24-cm, Nier-type spectrometer for rare gases; a 25.4-cm, Nier-type spectrometer for ratio measurements of He3/He4; a Gas Chromatograph-Quadrupole Mass Spectrometer for qualitative separation and analysis of organic compounds; a 30-cm-radius, solid-source, mass spectrometer for geochronology and isotope dilution analysis; and two units for respiratory gas analysis.

Underwater Research Areas (17). Located seaward off the campus is a marine research area set aside by the State of California. The taking of marine invertebrates and plants in this area is permitted only

Award of Appreciation from National Park Service (NPS) to the Institution and Director Nierenberg for Scripps's support and continuation of the NPS diver-training program, is viewed by, from left, J. D. Frautschy, assistant director; Dr. Nierenberg; Ray Freeman, deputy director of NPS's field operations; and James R. Stewart, chief diving officer, who has instructed more than 100 NPS rangers in advanced SCUBA techniques since Scripps began the program in 1963.



A tour of San Diego by 16 members of President Nixon's Citizens Advisory Committee on Environmental Quality included a stop at the Institution's Vaughan Aquarium-Museum. Here, Mayor Pete Wilson, left, a committee member, points out fish in aquarium tank to another committeeman, famed aviator and environmentalist Charles A. Lindbergh, second from right, and to the host for the visit, Scripps Asst. Dir. J. D. Frautschy, second from left, and his son, Kevin, 12, far right.

Glasheen Graphics

Champagne splashes in all directions as Mrs. Douglas L. Inman christens new Shore Processes Laboratory.
Shore Processes Laboratory

for scientific purposes. An adjoining ocean area is reserved by the Navy for Navy and Scripps research with bottom-mounted equipment.

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

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

Mt. Soledad Laboratory for the Study of Radioactivity. This laboratory, because of its highly specialized equipment and its isolation from other research areas where relatively large amounts of radioactivity are employed, provides for the study of characteristics of the natural radioactive background in the ocean. It also provides for detection and measurement of minute traces of artificial radioactivities that are entering the ocean and accumulating in many of its organisms as a result of weapon tests and the industrial and research use of nuclear materials. These studies yield information needed for predicting the impact expected from increased use of nuclear fuels in the future. This year, facilities were expanded for analyzing numerous biological samples of plutonium and other alpha emitters. The development of a computer-controlled flame spectrometer was completed and demonstrated with traces of natural cesium in the ocean; it obtained higher precision than ever reported previously.

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

San Vicente Lake Calibration Facility (30 miles northeast of San Diego). This facility, operated by the Marine Physical Laboratory, is equipped for testing and calibrating acoustic transducers used in oceanographic research. The equipment is located on an 8x15-m enclosed platform in 40 m water offering 1,372 m of unobstructed range.

Special Collections

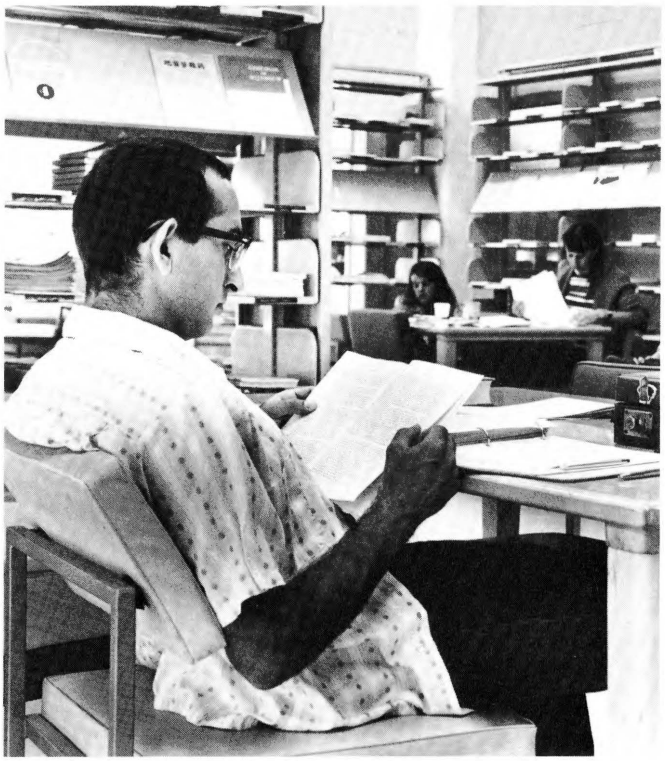
Geologic Data Center (5). Geologic data collected by Scripps vessels are cataloged and stored at this location. Index charts have been made for several hundred thousand nautical miles of expedition tracks through all sectors of the Pacific Ocean and part of the Arctic Ocean. Also available are overlays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

Marine Vertebrates (Fish Collection, 5 and 7). This consists of some 1,000,000 specimens of more than 2,500 cataloged species of marine fishes. Added in 1972-73 were 800 collections of bathypelagic and shore fishes.

Marine Invertebrates (Zooplankton Collection, 7). In this collection are nearly 53,000 fully documented zooplankton samples; of these more than 20,000 are from special expeditions and some 1,150 from Isaacs-Kidd mid-water trawls. Samples are supplemented by full meteorological, hydrographic, physical and chemical data.

Geological Samples (Storage locker is near Diving Facility). This collection contains some 4,000 geological samples, including 3,000 sediment cores. Also available for study are dredge-hauls of rocks and manganese nodules, taken mainly from the Pacific and Indian Oceans, and drill-cores near Guadalupe Island taken during the experimental Mohole operation.

Deep Sea Drilling Project Core Repository (18). Scripps houses the West Coast Repository for cores collected by DSDP. The DSDP is part of the National Science Foundation's (NSF) National Ocean Sediment Coring Program, and these collections are a national archive. Cores stored at this repository come from the Pacific and Indian Oceans. (Cores from the Atlantic, Mediterranean, Antarctic and Caribbean regions are stored at the East Coast Repository at

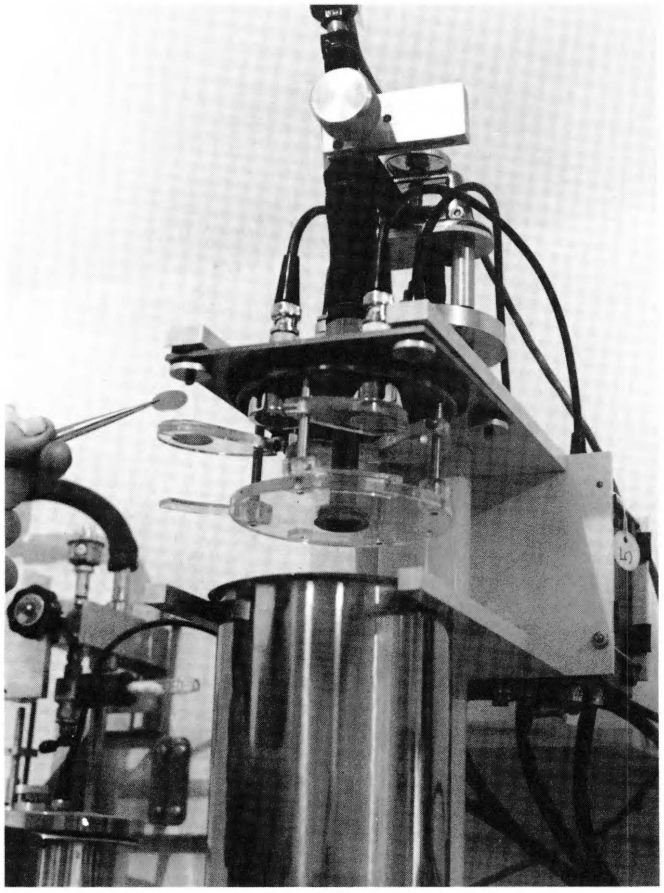


View of reading room in Scripps Library, which houses vast amount of oceanographic information, with outstanding collections in oceanography, marine biology, and undersea technology.

Lamont-Doherty Geological Observatory of Columbia University.) Samples from these cores are made available to qualified researchers throughout the world under policies established by NSF.

Oceanographic Data Archive (11). This collection includes more than 500,000 Pacific and Indian Ocean bathythermograph observations taken since 1941, tide gauge records taken since 1925 at Scripps Pier, and daily temperature and salinity records from Southern California shore stations taken since 1916. Summaries of the shore station data, issued annually, are available upon request.

Shore Processes Laboratory (3). The Shore Processes Laboratory is the research facility utilized by the Shore Processes Study Group, whose principal interest is the investigation of the nearshore environment. The facility was dedicated as a Sea Grant Program Coastal Zone Laboratory on March 24, 1973. The laboratory is located adjacent to the beach on the north side of Scripps Pier, a site that permits easy access to the beach or to offshore waters via the pier. The structure, a 3,000-square-foot multi-purpose building, includes an office, a laboratory, and shop space. An electronics laboratory and mechanical shop within the bulding are used for fabricating and maintaining instrumentation. The laboratory houses data acquisition and processing equipment, including a shore receiving station for telemetered data, analog and digital magnetic tape recorders, and strip-chart recorders. Data processing is achieved with an Interdata Model 70 computer equipped with a disc storage unit, digital tape recorders, a paper tape recorder, and CRT terminal. The laboratory includes a library that contains an extensive collection of reference material on coastal zone processes.



Technician at Mt. Soledad Laboratory installs sample in new, four-detector, alpha array with its vacuum system open.

PUBLICATIONS

The research being conducted at Scripps Institution of Oceanography is reflected in the publications of the faculty and staff. These publications, for the most part, are highly technical and range from short internal data reports to long genus revisions. Scripps publications are generally distributed by subscription, exchange or military contracts.

Below are listed the various Scripps Institution of Oceanography publications for 1972-1973, including information on their availability.

Bulletin

The *Scripps Institution of Oceanography Bulletin,* which contains lengthy papers by the faculty and staff, is the only Scripps publication available by subscription. For information about subscriptions and a list of those numbers available, please write: The University of California Press, 223 Fulton Street, Berkeley, California 94720.

The *Bulletin* volume issued during the last year is listed below:

Volume 20: GOPALAKRISHNAN, K. Developmental and Growth Studies of the Euphausiid *Nematoscelis difficilis* (Crustacea) Based on Rearing. March 1973. 87p.

Contributions

This publication is a compilation of selected reprints authored by the Scripps faculty and staff. The *Scripps Institution of Oceanography Contributions* is published annually and available only on an exchange basis. For information concerning exchanges please write: Gifts and Exchange Department, Library, University of California, San Diego, P.O. Box 2367, La Jolla, California 92037.

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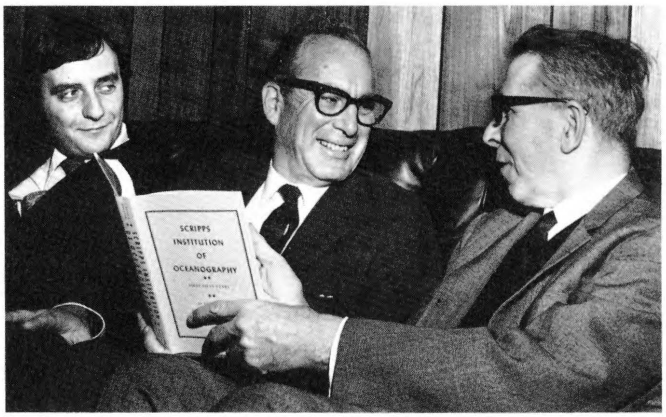

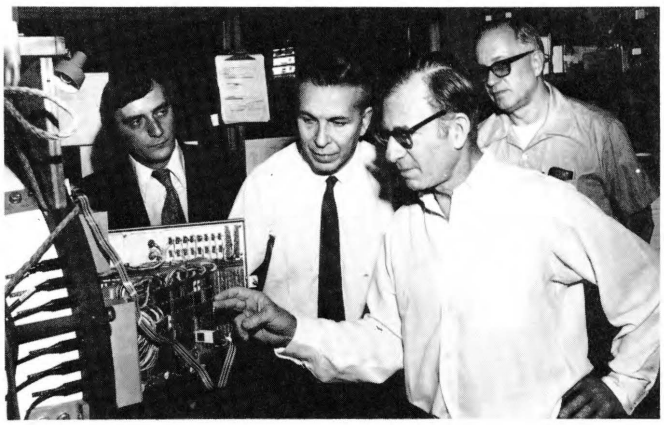

In top *photo, Director Nierenberg presents copy of* SIO: The First Fifty Years, *by Helen Raitt and Beatrice Moulton, to Jean-Pierre Levy, right, as Michel J. M. Beguery looks on. Levy is president of French National Center for Exploitation of the Oceans, Brest, France, and Beguery is science attaché in French Embassy, Washington. In* center *picture, Dr. Walter H. Munk, director, La Jolla Laboratories of the UC Institute of Geophysics and Planetary Physics, foreground, shows Beguery and Levy a recording system on modification of a deep-sea tide instrument for use in deep-ocean studies of internal waves, as Bernard Zetler, right, of IGPP staff, listens. In* bottom *photo, Levy and Beguery are given description of deep-ocean sediments by Dr. Melvin N. A. Peterson, manager, Deep Sea Drilling Project.*

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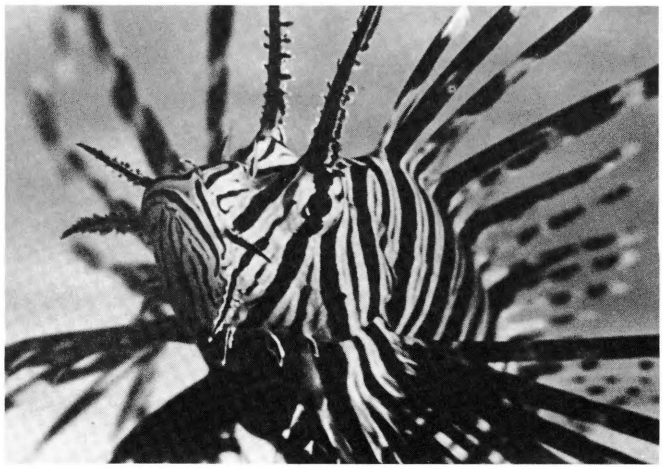

This poisonous lion-fish, Pterois sp., *is related to the California scorpion fish. Its venom is transported through hollow dorsal spines. The lion-fish occurs throughout the Indo-Pacific region. Several of them are displayed in the Vaughan Aquarium-Museum on the campus.*

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*Claude E. ZoBell	Marine Biology Research Division	Marine Microbiology

✓ Adjunct Professor series
* Emeritus
+ Visiting

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Appendix B
SPONSORS OF RESEARCH AND GRADUATE INSTRUCTION

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Department of Navigation and Ocean Development

FEDERAL:
Atomic Energy Commission
Environmental Protection Agency
National Aeronautics and Space Administration
National Science Foundation
Department of the Air Force
Department of the Army
  Corps of Engineers
Department of Commerce
  National Oceanic and Atmospheric Administration
  National Advisory Committee on Oceans and Atmosphere
  National Marine Fisheries Service
Department of Defense
  Advanced Research Projects Agency
Department of Health, Education, and Welfare
Department of the Interior
  Fish and Wildlife Service
  Geological Survey
Department of the Navy

OTHER:
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American Heart Association
American Optical Corporation
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Francis P. Shepard Foundation
A. P. Sloan Foundation
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Van Camp
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Scripps Industrial Associates
  Texaco, Incorporated
  Gulf Oil Corporation
  Sun Oil Company
  Continental Oil Company
  ESSO Production Research Company
  Shell Oil Company
  Union Oil Company
  AGIP
  Mobil Oil Corporation
  Société Nationale Des Pétroles d'Aquitaine
  Metallgesellshaft A. G.
  AMOCO International Oil Company
  Atlantic Richfield Company
  Chevron Oil Field Research Company

Appendix C
MAJOR AWARDS AND HONORS

Dr. Andrew A. Benson
  Received Stephen Hales Award of American Society of Plant Physiologists.
Dr. Joseph R. Curray
  Elected Councilor for Mineralogy by Society of Economic Paleontologists and Mineralogists.
Jeffery D. Frautschy
  Appointed by California State Senate Rules Committee to San Diego Regional Coastal Zone Conservation Commission and elected by Regional Commission to California State Coastal Zone Conservation Commission.
Dr. Myrl C. Hendershott
  Awarded A. B. Wood Medal and prize by Institute of Physics of London.
Dr. Jerome Namias
  Elected Councilor of American Meteorological Society.
Dr. William A. Nierenberg
  Received Presidential appointment as member of the National Science Board, the policy-making body of the National Science Foundation.
Victor Vacquier
  Awarded the John Adam Fleming Medal by American Geophysical Union.
Dr. Claude E. ZoBell
  The Second International U.S.-Japan Conference of Marine Microbiology was dedicated to him.
  Recognized by American Society for Microbiologists for his 40 years of "distinguished service to microbiology."

"For their contributions to marine science," these present and former faculty and staff members had undersea mountains in the northeast Pacific Ocean seabed named for them by the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce: Thomas E. Chase, Dr. Henry W. Menard, Dr. William A. Nierenberg, Arthur D. Raff, Dr. Russell W. Raitt, Dr. Roger R. Revelle, the late Dr. Milner B. Schaefer, Dr. George G. Shor, and Victor Vacquier.

Appendix D

RESEARCH VESSELS OF SCRIPPS INSTITUTION OF OCEANOGRAPHY

	Alexander Agassiz	Alpha Helix	Melville	Oconostota	Ellen B. Scripps	Thomas Washington	ST-908	FLIP	ORB
Type:	light freight	oceanographic research (biological)	oceanographic research	tug	off-shore supply	oceanographic research	harbor tug	floating instrument platform	oceanographic research buoy
Hull:	steel	steel	steel	steel	steel	steel	steel	steel	steel
Year Built:	1944	1965-1966	1969	1944	1964-1965	1965	1945	1962	1968
Year acquired by SIO:	1961	1966	1969	1962	1965	1965	1961	1962	1968
From whom acquired:	State Educational Agency for Surplus Property	National Science Foundation	U.S. Navy	U.S. Navy	Dantzler Boat and Barge Co.	U.S. Navy	U.S. Navy	Gunderson Bros. Shipbuilding Co.	U.S. Navy
Owner:	University of California	University of California	U.S. Navy	U.S. Navy	University of California	U.S. Navy	University of California	U.S. Navy	U.S. Navy
Length:	180'	133'	245'	102'	95'	209'	45'	355'	69'
Beam:	32'	31'	46'	25'	24'	40'	12'6"	20'/12'	45'
Draft:	10'	10'5½"	15'	10'	6'	14'	5'1"	10'/300'	fwd, 4'10½"/ aft 5'4½"
Displacement Tons (full):	825	512	2,075	206	115	1,362	28	2,100 (vertical)	299.5
Maximum speed:	11	10.5	12	11	9	12.5	9	varies -[1]	varies -[1]
Minimum speed:	0-1	0-3	0-1	0-1	1	0-1	1	varies -[1]	varies -[1]
Range (miles):	5,940	6,200	9,840	4,500	6,480	8,700	655	varies -[1]	varies -[1]
Endurance (days):	22	30	41	16	30	29	4	varies -[1]	30
Crew:	18	12	25	8	5	25	2	5	5
Scientific party:	13	12	25	6	8	17	—	11	12

[1] Depends on towing vessel

1972-73 TOTAL DAYS AT SEA 1,485

1972-73 NAUTICAL MILES STEAMED 152,224

Appendix E

DOCTOR OF PHILOSOPHY DEGREES AWARDED IN 1972-73 WITH TITLES OF DISSERTATIONS

Earth Sciences

Roger N. Anderson, "The Implications of Topography, Gravity, and Heat Flow on Midocean Ridges."

Ross O. Barnes, "Noble Gas Concentrations in the Pore Fluids of Marine Sediments Collected with an *In-situ* Pore Water Sampler." A sampler for collecting pore waters of marine sediments *in situ* was designed and constructed. Collected pore water samples were analyzed for inert gas concentrations to evaluate the flux of helium from the marine sedimentary column.

John Douglas Macdougall, "Particle Track Records in Natural Solids from Oceans on Earth and Moon." A method involving study of the radiation damage produced in metal materials by spontaneous fission of uranium impurities (fission track dating) is investigated for determining ages of oceanic rocks and sediments. The method is successfully applied to glass shards in volcanic ash layers, and with some exceptions, to oceanic salts. The second part of this thesis deals with the lunar regolith as an extraterrestrial sediment, and attempts to delineate dynamic processes occurring on the moon surface through study of cosmic ray produced effects.

Marine Biology

Charles K. Barry, "Experimental Analysis of Habitat Selection in the Plant-Inhabiting Shrimps of the Genus *Hippolyte* in Southern California." Cryptic shrimps of the genus *Hippolyte* rely heavily on visual cues in the selection of their host plants from a distance, with emphasis on shape (striped-like pattern) and color. Other cues that are utilized for proximate recognition include mechanical stimuli (leaf width and thickness) and chemical stimuli from the preferred plants.

Robert C. May, "Effects of Temperature and Salinity on the Eggs and Early Larvae of the Sciaenid Fish, *Bairdiella icistia* (Jordan and Gilbert)."

John E. McCosker, "The Osteology, Classification, and Relationships of the Eel Family Ophichthidae (Pisces, Anguilliformes)." The evolution and relationships of the 40 genera of snake eels are discussed, based on the study of their anatomy.

Joane S. Molenock, "Evolutionary Aspects of Communication in the Courtship and Agonistic Behavior of Four Species of Crabs (Anomura, *Petrolisthes*)." The four California species of porcelain crabs of the genus *Petrolisthes* have evolved different patterns of social and reproductive behavior.

Christopher J. Platt, "Central Control of Postural Orientation in Flatfish."

Rosemary A. Thompson, "Mechanisms of Osmoregulation in a Euryhaline Goby, *Gillichthys mirabilis:* the Role of Active and Passive Transport of Sodium and Chloride Ions Across the Gills." This was a study of the mechanism by which certain fish can adapt from fresh-water to salt-water environments. Specifically, for the first time in fish, it was demonstrated that the key process is active excretion of chloride by the gills.

Oceanography

David W. Behringer, "Investigations of Large Scale Oceanic Circulation Using Historical Hydrographic Data."

K. Gopalakrishnan, "Biology and Zoogeography of the Genus *Nematoscelis* (Crustacea, Euphausiacea)."

John A. Grow, "A Geophysical Study of the Central Aleutian Arc."

Peter W. Hacker, "The Mixing of Heat Deduced from Temperature Fine Structure Measurements in the Pacific Ocean and Lake Tahoe."

Ann C. Hartline, "The Ecology of the Subtidal Acorn Barnacle, *Balanus pacificus Pilsbry.*"

Jed Hirota, "Quantitative Natural History of *Pleurobrachia bachei* A. Agassiz in La Jolla Bight."

David C. Judkins, "A Revision of the Decapod Crustacean Genus *Sergestes* (Natantia, Penaeidea) *Sensu latu,* with Emphasis on the Systematics and Geographical Distribution of *Neosergestes*, New Genus."

Daniel L. Kamykowski, "Some Physical and Chemical Aspects of the Phytoplankton Ecology of the La Jolla Bay."

Dale A. Kiefer, "Cellular Chlorophyll *a* Fluorescence in Phytoplankton." Studies in the ocean and laboratory of chlorophyll *a* fluorescence showed that the intensity of red light emission by chlorophyll within the phytoplankton cell is variable. This variability is a function of the cell's response to variations in ambient light intensity and the nutrional state of the cell.

Bert N. Kobayashi, "Systematics, Zoogeography and Aspects of the Life History of the Bathypelagic Fish Genus *Cyclothone* in the Pacific Ocean."

Genelle W. Renz, "The Distribution and Ecology of Radiolaria in the Central Pacific - Plankton and Surface Sediments."

Edward R. Sholkovitz, "The Chemical and Physical Oceanography and the Interstitial Water Chemistry of the Santa Barbara Basin."

Paul M. Yoshioka, "The Population Dynamics and Ecology of the Encrusting Ectoproct *Membranipora serrilamella.*"

MASTER OF SCIENCE DEGREES AWARDED IN 1972-73

Earth Sciences

Alan B. Chatfield
Clarke R. Wilson

Oceanography

Laurence E. Deysher
James Schweigert

Marine Biology

Gordon Lusk

Appendix F

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Mark N. Christensen (From July 1, 1974)
Chancellor at Santa Cruz
Ivan H. Hinderaker
Chancellor at Riverside

Dr. Jon Sharp

Appendix G

CURRENT FUNDS EXPENDITURES BY MAJOR UNITS AND FUNCTIONS BY FUND SOURCE 1972-1973

	Institutes			
	Scripps Institution of Oceanography	Geophysics and Planetary Physics	Marine Resources	Total
STATE OF CALIFORNIA				
General	$3,329,519	$144,089	$206,886	$3,680,494
Other	83,094	—	15,840	98,934
Total State of California	3,412,613	144,089	222,726	3,779,428
STUDENT TUITION AND FEES	—	—	—	—
UNITED STATES OF AMERICA				
Grants-				
Department of Defense- Air Force	—	—	—	—
Department of Health, Education and Welfare	45,282	903	574	46,759
National Aeronautics and Space Administration	113,232	—	—	113,232
National Institutes of Health	163,369	—	—	163,369
National Science Foundation	5,785,779	387,889	183,437	6,357,105
Other	589,515	39,768	—	629,283
Total Grants	6,697,177	428,560	184,011	7,309,748
Contracts-				
Atomic Energy Commission	173,204	—	258,143	431,347
Department of Defense				
Air Force	326,159	—	—	326,159
Army	203,855	—	—	203,855
Navy	7,937,659	418,566	—	8,356,225
Department of Health, Education and Welfare	—	—	—	—
National Aeronautics and Space Administration	—	—	—	—
National Science Foundation	8,631,661	—	467	8,632,128
Other	141,921	—	42,097	184,018
Total Contracts	17,414,459	418,566	300,707	18,133,732
Total United States of America	24,111,636	847,126	484,718	25,443,480
ENDOWMENT FUNDS	403,619	4,830	129	408,578
GIFTS AND PRIVATE GRANTS	347,870	7,559	3,829	359,258
SALES AND SERVICES	37,766	−12,358	24,140	49,548
ORGANIZED ACTIVITIES	1,598	—	—	1,598
OTHER SOURCES	12,375	—	21,278	33,653
AUXILIARY ENTERPRISES	—	—	—	—
RESERVES	—	—	—	—
Total Current Funds Expenditures	$28,327,477	$991,246	$756,820	$30,075,543

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